Present state of the Temple of Serapis at Puzzuoli.

London, Published by John Murray, Albemarle Street, April 1834.

PRINCIPLES

OF

GEOLOGY:

BEING

AN INQUIRY HOW FAR THE FORMER CHANGES OF THE EARTH'S SURFACE

ARE REFERABLE TO CAUSES NOW IN OPERATION.

BY

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"Amid all the revolutions of the globe, the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

Playfair, *Illustrations of the Huttonian Theory*, § 374.

IN FOUR VOLUMES.

VOL. I.

THE FOURTH EDITION.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1835.

PREFACE.

In the Preface to the last Edition, I gave a list of the places where new matter had been introduced, or where opinions expressed in former Editions had been modified or renounced. I shall now again subjoin a similar list for the sake of those readers who have already studied this work, but who may wish to refer at once to the additions and corrections now made for the first time.

List of the principal Alterations, Additions, and Omissions in the Fourth Edition.

	VOL.	P.
Hutton and Playfair on Origin of Valleys - -	I.	92.
On the climate of Europe when it was inhabited by the Mammoth, Rhinoceros, Hippopotamus, and other fossil mammalia of extinct species - -		141.
Speculations on the manner in which remains of the Siberian Mammoth and Rhinoceros became imbedded in frozen mud and ice - - -		145.
Effects of currents on climate - - -		165.
Temperature of Southern hemisphere - -		171.
Laplace on Depth of the Ocean - -		180.
The eighth chapter, on the former geological states of the earth's surface as connected with successive changes of climate, entirely recast - - -		194.
On vertebrated remains in the Transition and other strata, and their bearing on the theory of progressive development - - -		227 to 234.

List of Alterations, &c.	VOL.	P.
Two wood-cuts of jaws of fossil quadrupeds from Stonesfield - - - -	I.	232.
Blocks drifted by ice in the Baltic - - -		267.
Professor Sedgwick's opinion of concretionary arrangement of Magnesian limestone admitted - -		314, 315.
Discussion on the rise of land in Sweden omitted here, and postponed to chap. xvii. book ii. - -		341.
The glossary inserted here instead of at the end of the fourth volume - - - -		376.
Rennell on the Gulf Stream and other principal Currents	II.	4.
Two views of Reculver Church taken in 1781 and 1834		36, 37.
Channel recently excavated by a current in Lake Erie		64.
No eruption of Jorullo in 1819 - - -		190.
Mr. Cuming on the Chilian Earthquake of 1822 -		233.
Pl. VI. View of Fort of Sindree as it appeared before the earthquake of 1819 - - -		238.
Elevation and subsidence of land without earthquakes		331 to 349.
Geological and other proofs of the gradual rise of land in Sweden observed by the author during a tour in that country in 1834 - - - -		*ib.*
Herschel on the Mode in which the Centrifugal Force, co-operating with Aqueous Causes, might gradually have reduced the Earth to the Form of an Oblate Spheroid - - - -		352.
Wood-cut of the Leming - - - -	III.	58.
Wood-cut of Mydaus meliceps - - -		60.
Drifting of quadrupeds on trees by the Amazon -		63.
Honey-bee transplanted to America - -		85.
The discussion on the influence of vegetation abridged		181.
Buried Hindoo town - - - -		221.
Fossil eggs of turtles from Ascension, with two wood cuts		290.
Mr. Stutchbury on elevated Coral Reef many thousand feet high, in Otaheite - - -		318.
Chapters ii. iii. and iv. of the Fourth Book, rearranged		333.
A portion of my original Preface inserted here relating to the observations made during my tours on the Continent in 1829–30–31, and to the co-operation of M. Deshayes and others -		385

List of Alterations, &c.	VOL.	P.
Wood cut of *Lucina divaricata* - - -	III.	394.
Wood cut of *Melania inquinata* - - -		*ib.*
A more correct view of Isle of Cyclops, by Capt. B. Hall, substituted for one before given - -		425.
Plate VIII. substituted for a coloured plate formerly given. Extent of view on the left widened -		430.
Plate IX. A new view looking down the Val del Bove, with description of it - - - -		432.
Division of the Crag into the coralline and red crag -	IV.	86.
Wood cuts of recent species of Cypris - -		163.
Wood cut of Cerithium cinctum - - -		183.
Wood cuts of Cardium porulosum - -		189.
Auvergne alluviums in ancient fissures - -		211.
Professor Parrot's retraction of his opinion that a great difference of level exists between the Caspian and Black seas - - - -		215.
Deposit called the Elephant Bed, at Brighton -		274.
Ancient and modern classification of Fossiliferous strata - - - - - -		281 to 284.
Relations of the Wealden fossils to the Green-sand above and Oolite below - - -		296.
New red-sandstone distinguished from the magnesian limestone group - - - -		300.
Old red-sandstone separated from the carboniferous group - - - - - - -		303.
Wood-cut of Cephalaspis Lyellii - -		304.
Professor Sedgwick on the Difference between Stratification, Cleavage, and the Jointed Structure -		361 to 366.
Wood-cut showing parallel planes of cleavage intersecting curved strata - - - -		363.
Columnar structure in ice - - -		367.
Strata not always altered by contact with dikes -		373.
Dufrénoy on Lias and Chalk of the Pyrenees altered by Granite - - - - - -		375.
Some objections to the metamorphic theory considered		383.

On former occasions I have acknowledged the valuable assistance afforded me by several of my friends in the execution of this work, and have especially alluded to the zealous co-operation of Mr. Murchison, Mr. Broderip, Dr. Fitton, and Mr. Lonsdale. I have now to express my thanks to Capt. Basil Hall for the improvements which he has suggested in the present edition, and for his having visited, at my request, several places in Italy and Sicily, with a view of obtaining for me more exact information on points on which I had entertained doubts.

The original MS. of the Principles of Geology was delivered to the publisher in 1827; but the greater portion of it was then in an unfinished state, the chapters on the early history of Geology and those on "the Inorganic Causes of Change," being the only ones then nearly ready for the press. The work was at that time intended to form two octavo volumes, which were to appear in the course of the year following. Their publication, however, was delayed by various geological tours which I made in the years 1828, 1829, 1830, and 1831, in France, Italy, Sicily, and Germany. The following were the dates when the successive volumes and editions finally appeared;—

1st Vol. in octavo	- -	Jan. 1830.
2d Vol. do.	- -	Jan. 1832.
1st Vol. 2d ed. in octavo	-	1832.
2d Vol. 2d ed. do.	-	Jan. 1833.
3d Vol. 1st ed. do.	-	May, 1833.
New edition of the whole work in 4 vols. 12mo.	-	May, 1834.

Before the spring of 1828 I had been at various times occupied in the inquiry how far it might be possible to explain geological phenomena by reference to changes now going on in the globe; and I had previously made geological tours both in England and France, in company with Professor C. Prevost of Paris, a writer well known to have laboured successfully in the same field of investigation. I had also examined, before I drew up the first outline of my work, the geology of part of Hampshire and Forfarshire, and had given some account of my observations to the Geological Society of London. During the early part of 1827, I was engaged in preparing for publication an article on "Scrope's Geology of Central France," which appeared in the Quarterly Review in the October of that year. I was then led to reflect much on the extent to which one class of geological phenomena, namely, those relating to the igneous rocks, might be solved by the study of the operations of active volcanos. It is but justice to preceding authors to state that the

chapters which now appear in my fourth book on Auvergne, Cantal, Velay, and the Vivarais, were in great part written as they now stand before I had visited Central France; so well had I become acquainted with the scenery of those regions of extinct volcanos by studying the beautiful panoramic views which illustrate Mr. Scrope's work, and by reading his graphic descriptions of the country, and those borrowed by him from Montlosier. It will be found also that the speculations in which I have indulged in the article above referred to in the Quarterly Review are in unison with the opinions I now hold.

I have alluded more particularly in the text to the co-operation of several geologists and naturalists who contributed towards the perfecting of different parts of my work, and have mentioned the principal additions which I made subsequently to the spring of 1828. I shall now merely add, that the 3rd book, on the "Changes of the Organic World," which consisted in the original MS. merely of four or five short chapters, was expanded in 1831 into a treatise occupying the 2d volume of my first edition.

Glossary.—Being informed by several readers of my third edition, that they only discovered the Glossary when they arrived at the last volume,

I have in this instance appended it to the end of the first volume, in order that it may be conveniently referred to by those who are beginning the work.

If any person, in studying the Principles of Geology, should be lost in the digressions on collateral subjects which are introduced here and there, especially those relating to natural history in the third book, and should be unable to see the bearing of these on the topics which are more strictly geological, they are invited to refer from time to time to the annexed Summary, and to consult in connexion with it the abridged Table of Contents which follows at p. xv.

SUMMARY

OF THE

PRINCIPLES OF GEOLOGY.

After some observations on the nature and objects of Geology (Chap. I. Vol. I.), a sketch is given of the progress of opinion in this science, from the times of the earliest known writers to our own days (Chaps. II. III. IV.). From this historical sketch it appears that the first cultivators of geology indulged in many visionary theories, the errors of which the author refers chiefly to one common source, — a prevailing persuasion that the ancient causes of change were different, both as regards their nature and energy to those now in action; in other words, they supposed that the causes by which the crust of the earth, and its habitable surface, have been modified at remote periods, were almost entirely distinct from the operations by which the surface and crust of the planet are now undergoing a gradual change. The prejudices which led to this assumed discordance of ancient and modern causes are then considered (Chap. V. to p. 122. Vol. I.), and the author contends, that neither the imagined universality of certain sedimentary formations (Chap. V.), nor the different climates which formerly pervaded

the northern hemisphere (Chaps. VI. VII. VIII.), nor the alleged progressive development of organic life (Chap. IX.), lend any solid support to the assumption.

The numerous topics of general interest brought under review in discussing this fundamental question are freely enlarged upon, in the hope of stimulating the curiosity of the reader. It is presumed that when he has convinced himself, that the forces formerly employed to remodel the crust of the earth were the same in kind and energy as those now acting, or even if he perceives that the opposite hypothesis is, at least, questionable, he will enter upon the study of the two treatises which follow (on the Changes now in progress in the Organic and Inorganic World, Books II. and III.) with a just sense of the importance of their subject matter, and its direct bearing on Geology.

The first of these treatises, which relates to the changes of the inorganic creation, such as are known to have taken place within the historical era, is divided into two parts. In the first an account is given of the observed effects of aqueous causes, such as rivers, springs, tides, and currents (Book II. Chaps. I. to VIII.); in the second the effects and probable causes of the volcano and earthquake, and all subterranean movements, are considered (Book II. Chaps. IX. to XIX.).

The treatise on the changes of the organic world is also divisible into two parts; the first of which comprehends all questions relating to the variability of species, and the limits assigned to their duration (Chaps. I. to XI.). The second explains the processes by which the remains of animals and plants existing at any particular period may be preserved, or become fossil (Chaps. XII. to XVII.).

Under the first of these divisions, the author defines the term *species*, and combats the notion that one species may be gradually converted into another by insensible modifications in the course of ages (Chaps. I. II. III. and IV.). He also enters into a full examination of the evidence regarded by him as conclusive in favour of the limited durability of species. In proof of this, he argues that the geographical distribution of species being partial, the changes constantly going on in the animate and inanimate world must constantly tend to their extinction (Chaps. V. to X.). Whether new species are substituted for those which die out, is a topic on which no decided opinion is offered; but it is contended that if new species had been introduced from time to time as often as others have been lost, we should have no reason to expect to be able to establish the fact during the limited period of our observation (Chap. XI.).

In the second branch of this treatise, the various circumstances under which aquatic and terrestrial plants and animals, as also man and the works of his hands, become fossil, are examined (Chaps. XIII. to XVII.).

The fourth book is occupied with the description of geological monuments strictly so called, the formations termed tertiary being first more fully examined and classified, the secondary and primary rocks being afterwards more briefly alluded to. In the course of this description, it appears that the rocks which compose the crust of the earth have resulted in part from igneous and partly from aqueous causes; others from the combined influence of these agents, the igneous having operated both upon and far beneath the surface. The bearing of the various phenomena

considered in the second book on the interpretation of such monuments cannot fail to be seen.

It is, moreover, shown, that the fossil remains of plants and animals are plentifully included in aqueous rocks of different ages, and that these belong for the most part to species which no longer exist on the earth. It is principally by the aid of such fossils, that the chronological arrangement of rocks is determined; and a careful comparison of the numerous organic remains of the tertiary formations affords some indication of a gradual introduction of the species now living, and a successive extinction of species which previously existed. It is at least clear that during the tertiary epoch entire assemblages of species were not simultaneously swept away from large regions, and others perfectly distinct created in their place. The intimate connection of these phenomena with the subjects investigated in the third book, is sufficiently obvious.

TABLE OF CONTENTS.

		Vol. I.
Book I. Chap. I.	Objects and Nature of Geology -	p. 1
II. III. IV.	Historical Sketch of the Progress of Geology - - -	6
V.	Theoretical Errors which have retarded the Progress of Geology - -	109
VI. VII. VIII.	Assumed Discordance of the ancient and existing Causes of Change controverted — Climate - -	135
IX.	The same Question considered in reference to the Theory of the progressive Development of Organic Life -	222
Book II. Chap. I.	Aqueous Causes — Action of running Water - - - -	254
II.	Rivers — Floods - - -	275
III.	Phenomena of Springs - -	296
IV.	Deposits in Deltas of Lakes and inland Seas - - - -	332
V.	Oceanic Deltas - - -	353
		Vol. II.
VI. VII.	Tides and Currents—Destroying Effects	p. 1.
VIII.	Tides and Currents — Reproductive Effects - - - -	74
IX.	Igneous Causes — Volcanic Regions -	89
X. XI.	Volcanic District of Naples - -	113
XII.	Etna — Its modern Lavas - -	164
XIII.	Lancerote — Submarine Volcanos — Theory of Elevation Craters -	191

Book II.		Vol. II.
Chap. XIV.	Earthquakes of the last Fifty Years -	p. 227
XV.	Earthquake of Calabria in 1783 -	254
XVI.	Earthquakes, continued — Temple of Serapis - - - -	292
XVII.	Elevation and Subsidence of Land without Earthquakes - - -	331
XVIII.	Causes of Volcanic Heat - -	350
XIX.	Causes of Earthquakes - -	375
Book III. Ch. I.	Changes of the Organic World—Reality of Species - - -	404
II.	Theory of Transmutation of Species untenable - - -	426
III.	Limits of the Variability of Species -	449
		Vol. III.
IV.	Hybrids - - - -	p. 1
V. VI. VII.	Geographical Distribution of Species -	22
VIII. IX.	Changes in the Animate World, which tend to the Extinction of Species -	98
X.	Changes in the Inorganic World, tending to the Extinction of Species -	142
XI.	Whether the Extinction and Creation of Species can now be in progress -	164
XII.	Modifications in Physical Geography caused by Plants, the inferior Animals, and Man - - -	175
XIII.	How Plants and Animals become Fossil in Peat, Blown Sand, and Volcanic Matter - - - -	198
XIV.	Burying of Fossils in alluvial Deposits and Caves - - -	218
XV.	Imbedding of Organic Remains in the Deposits of Seas and Lakes -	240
XVI.	How the Remains of Man and his Works are becoming Fossil beneath the Waters - - -	258

Book III. Vol. III.

Chap. XVII. How Fresh-water and Marine Plants and Animals are becoming Fossil in subaqueous Strata - - - p. 281

Book IV. Ch. I. On the Connexion of the Second and Third Books with the Fourth - - 325

II. General Arrangement of Materials in the Earth's Crust, and Rules for determining the relative Ages of Rocks - - - - - 333

III. Discovery of successive Groups of successive Periods - - - 354

IV. Different Circumstances under which the Secondary and Tertiary Formations may have originated - - 363

V. Subdivision of Tertiary Formations considered chronologically - - 378

VI. Newer Pliocene Formations — Sicily 404

VII. VIII. Rocks of the same Age in Etna - 420

Vol. IV.

IX. Changes since the Formation of the Newer Pliocene Strata in Sicily - p. 1

X. Newer Pliocene Formations, marine and volcanic - - - 16

XI. Fresh-water and Alluvial of the same Period - - - - 42

XII. Older Pliocene Formations - - 63

XIII. Crag of Norfolk and Suffolk - 85

XIV. Volcanic Rocks of the Older Pliocene Period - - - - 102

XV. Miocene Formations — marine - 127

XVI. Alluvial — fresh-water — volcanic - 147

XVII. Eocene Formations — fresh-water - 156

XVIII. ——————— — Paris Basin - 177

XIX. ——— Volcanic Rocks - - 197

XX. ——— Formations of different Countries and of England - - 221

Book IV. Vol. IV.

Ch. XXI. XXII. Origin of the English Eocene Formations and Denudation of the Weald p. 233

XXIII. Secondary Formations - - 281

XXIV. Analogy of the older Fossiliferous to the Tertiary Strata - - - 314

XXV. Relative Antiquity of Mountain Chains 327

XXVI. On the Rocks commonly called Primary — unstratified - - 343

XXVII. On the Stratified Rocks called Primary 360

DIRECTIONS TO THE BINDER.

Frontispiece *to face* Title-page, Vol. I.

			Page
Plate	I.	Vol. I.	189
	II.	—	209
	III.	Vol. II.	99
	IV.	—	113
	V.	—	237
	VI.	—	238
	VII.	Vol. III.	404
	VIII.	—	430
	IX.	—	432
	X.	Vol. IV.	73
	XI.	—	103
	XII.	—	128
	XIII.	—	189
	XIV.	—	190
	XV.	—	233

PRINCIPLES OF GEOLOGY.

BOOK I.

CHAPTER I.

Geology defined — Compared to History — Its relation to other Physical Sciences — Not to be confounded with Cosmogony.

Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature: it inquires into the causes of these changes, and the influence which they have exerted in modifying the surface and external structure of our planet.

By these researches into the state of the earth and its inhabitants at former periods, we acquire a more perfect knowledge of its present condition, and more comprehensive views concerning the laws now governing its animate and inanimate productions. When we study history, we obtain a more profound insight into human nature, by instituting a comparison between the present and former states of society. We trace the long series of events which have gradually led to the actual posture of affairs; and by connecting effects with their causes, we are enabled to classify and retain in the memory a multitude of complicated relations — the various peculiarities of national character — the dif-

ferent degrees of moral and intellectual refinement, and numerous other circumstances, which, without historical associations, would be uninteresting or imperfectly understood. As the present condition of nations is the result of many antecedent changes, some extremely remote and others recent, some gradual, others sudden and violent, so the state of the natural world is the result of a long succession of events; and if we would enlarge our experience of the present economy of nature, we must investigate the effects of her operations in former epochs.

We often discover with surprise, on looking back into the chronicles of nations, how the fortune of some battle has influenced the fate of millions of our contemporaries, when it has long been forgotten by the mass of the population. With this remote event we may find inseparably connected the geographical boundaries of a great state, the language now spoken by the inhabitants, their peculiar manners, laws, and religious opinions. But far more astonishing and unexpected are the connections brought to light, when we carry back our researches into the history of nature. The form of a coast, the configuration of the interior of a country, the existence and extent of lakes, valleys, and mountains, can often be traced to the former prevalence of earthquakes and volcanos in regions which have long been undisturbed. To these remote convulsions the present fertility of some districts, the sterile character of others, the elevation of land above the sea, the climate, and various peculiarities, may be distinctly referred. On the other hand, many distinguishing features of the surface may often be ascribed to the operation, at a remote era, of slow and tranquil causes — to the gradual deposition of sediment in a

lake or in the ocean, or to the prolific increase of testacea and corals.

To select another example, we find in certain localities subterranean deposits of coal, consisting of vegetable matter, formerly drifted into seas and lakes. These seas and lakes have since been filled up, the lands whereon the forests grew have disappeared or changed their form, the rivers and currents which floated the vegetable masses can no longer be traced, and the plants belonged to species which for ages have passed away from the surface of our planet. Yet the commercial prosperity, and numerical strength of a nation, may now be mainly dependent on the local distribution of fuel determined by that ancient state of things.

Geology is intimately related to almost all the physical sciences, as history is to the moral. An historian should, if possible, be at once profoundly acquainted with ethics, politics, jurisprudence, the military art, theology; in a word, with all branches of knowledge by which any insight into human affairs, or into the moral and intellectual nature of man, can be obtained. It would be no less desirable that a geologist should be well versed in chemistry, natural philosophy, mineralogy, zoology, comparative anatomy, botany; in short, in every science relating to organic and inorganic nature. With these accomplishments, the historian and geologist would rarely fail to draw correct and philosophical conclusions from the various monuments transmitted to them of former occurrences. They would know to what combination of causes analogous effects were referable, and they would often be enabled to supply, by inference, information concerning many events unrecorded in the defective

archives of former ages. But as such extensive acquisitions are scarcely within the reach of any individual, it is necessary that men who have devoted their lives to different departments should unite their efforts; and as the historian receives assistance from the antiquary, and from those who have cultivated different branches of moral and political science, so the geologist should avail himself of the aid of many naturalists, and particularly of those who have studied the fossil remains of lost species of animals and plants.

The analogy, however, of the monuments consulted in geology, and those available in history, extends no farther than to one class of historical monuments, — those which may be said to be *undesignedly* commemorative of former events. The canoes, for example, and stone hatchets found in our peat bogs, afford an insight into the rude arts and manners of the earliest inhabitants of our island; the buried coin fixes the date of the reign of some Roman emperor; the ancient encampment indicates the districts once occupied by invading armies, and the former method of constructing military defences: the Egyptian mummies throw light on the art of embalming, the rites of sepulture, or the average stature of the human race in ancient Egypt. This class of memorials yields to no other in authenticity, but it constitutes a small part only of the resources on which the historian relies, whereas in geology it forms the only kind of evidence which is at our command. For this reason we must not expect to obtain a full and connected account of any series of events beyond the reach of history. But the testimony of geological monuments, if frequently imperfect, possesses at least the advantage of being free from all suspicion of misrepresentation. We may be deceived in the inferences which we draw, in the

same manner as we often mistake the nature and import of phenomena observed in the daily course of nature; but our liability to err is confined to the interpretation, and, if this be correct, our information is certain.

It was long before the distinct nature and legitimate objects of geology were fully recognized, and it was at first confounded with many other branches of inquiry, just as the limits of history, poetry, and mythology were ill-defined in the infancy of civilization. Even in Werner's time, or at the close of the eighteenth century, geology appears to have been regarded as little other than a subordinate department of mineralogy; and Desmarest included it under the head of Physical Geography. But the most common and serious source of confusion arose from the notion that it was the business of geology to discover the mode in which the earth originated, or, as some imagined, to study the effects of those cosmological causes which were employed by the Author of Nature to bring this planet out of a nascent and chaotic state into a more perfect and habitable condition. Hutton was the first who endeavoured to draw a strong line of demarcation between his favourite science and cosmogony, for he declared that geology was in nowise concerned "with questions as to the origin of things."

An attempt will be made in the sequel of this work to demonstrate that geology differs as widely from cosmogony, as speculations concerning the mode of the first creation of man differ from history. But, before entering more at large on this controverted question, it will be desirable to trace the progress of opinion on this topic, from the earliest ages to the commencement of the present century.

CHAPTER II.

HISTORICAL SKETCH OF THE PROGRESS OF GEOLOGY.

Oriental Cosmogony — Doctrine of the successive destruction and renovation of the world — Origin of this doctrine — Common to the Egyptians (p. 12.) — Adopted by the Greeks — System of Pythagoras — of Aristotle (p. 20.) — Dogmas concerning the extinction and reproduction of genera and species — Strabo's theory of elevation by earthquakes (p. 24.) — Pliny — Concluding Remarks on the knowledge of the Ancients.

Oriental Cosmogony. — THE earliest doctrines of the Indian and Egyptian schools of philosophy agreed in ascribing the first creation of the world to an omnipotent and infinite Being. They concurred also in representing this Being, who had existed from all eternity, as having repeatedly destroyed and reproduced the world and all its inhabitants. In the "Institutes of Menù," the sacred volume of the Hindoos, to which, in its present form, Sir William Jones ascribes an antiquity of at least eight hundred and eighty years before Christ, we find this system of the alternate destruction and renovation of the world proposed in the following remarkable verses: —

"The Being, whose powers are incomprehensible, having created me (Menù) and this universe, again became absorbed in the supreme spirit, changing the time of energy for the hour of repose.

"When that power awakes, then has this world its full expansion; but when he slumbers with a tranquil spirit, then the whole system fades away. . . . . For

while he reposes as it were, embodied spirits endowed with principles of action depart from their several acts, and the mind itself becomes inert."

Menù then describes the absorption of all beings into the Supreme essence, and the Divine soul itself is said to slumber, and to remain for a time immersed in "the first idea, or in darkness." He then proceeds (verse fifty-seven), "Thus that immutable power, by waking and reposing alternately, revivifies and destroys, in eternal succession, this whole assemblage of locomotive and immoveable creatures."

It is then declared that there has been a long succession of *manwantaras*, or periods, each of the duration of many thousand ages, and —

"There are creations also, and destructions of worlds innumerable: the Being, supremely exalted, performs all this with as much ease as if in sport, again and again, for the sake of conferring happiness." *

The compilation of the ordinances of Menù was not all the work of one author nor of one period, and to this circumstance some of the remarkable inequalities of style and matter are probably attributable. There are many passages, however, wherein the attributes and acts of the "Infinite and Incomprehensible Being" are spoken of with much grandeur of conception and sublimity of diction, as some of the passages above cited, though sufficiently mysterious, may serve to exemplify. There are at the same time such puerile conceits and monstrous absurdities in this cosmogony, that some may be disposed to impute to mere accident any slight approximation to truth, or apparent coin-

* Institutes of Hindoo Law, or the Ordinances of Menù, from the Sanscrit, translated by Sir William Jones, 1796.

cidence between the oriental dogmas and observed facts. This pretended revelation, however, was not purely an effort of the unassisted imagination, nor invented without regard to the opinions and observations of naturalists. There are introduced into it certain astronomical theories, evidently derived from observation and reasoning. Thus, for instance, it is declared that, at the North Pole, the year was divided into a long day and night, and that their long day was the northern, and their night the southern course of the sun; and to the inhabitants of the moon, it is said, one day is equal in length to one month of mortals.* If such statements cannot be resolved into mere conjectures, we have no right to refer to mere chance the prevailing notion, that the earth and its inhabitants had formerly undergone a succession of revolutions and catastrophes interrupted by long intervals of tranquillity.

Now there are two sources in which such a theory may have originated. The marks of former convulsions on every part of the surface of our planet are obvious and striking. The remains of marine animals imbedded in the solid strata are so abundant, that they may be expected to force themselves on the observation of every people who have made some progress in refinement; and especially where one class of men are expressly set apart from the rest for study and contemplation. If these appearances are once recognized, it seems natural that the mind should conclude in favour, not only of mighty changes in past ages, but of alternate periods of repose and disorder;—of repose, when the fossil animals lived, grew, and

* Menù, Inst. c. i. 66, and 67.

multiplied — of disorder, when the strata in which they were buried became transferred from the sea to the interior of continents, and were uplifted so as to form part of high mountain chains. Those modern writers, who are disposed to disparage the former intellectual advancement and civilization of eastern nations, may concede some foundation of observed facts for the curious theories now under consideration, without indulging in exaggerated opinions of the progress of science; especially as universal catastrophes of the world, and exterminations of organic beings, in the sense in which they were understood by the Brahmin, are untenable doctrines.

We know that the Egyptian priests were aware, not only that the soil beneath the plains of the Nile, but that also the hills bounding the great valley, contained marine shells*; and it could hardly have escaped the observation of eastern philosophers, that some soils were filled with fossil remains, since so many national works requiring extensive excavations were executed by oriental monarchs in very remote eras. They formed canals and tanks on a magnificent scale, and we know that in more recent times (the fourteenth century of our era) the removal of soil necessary for such undertakings brought to light geological phenomena, which attracted the attention of a people less civilized than were many of the older nations of the East.†

* Herodot. Euterpe, 12.

† This circumstance is mentioned in a Persian MS. copy of the historian Ferishta, in the library of the East India Company, relating to the rise and progress of the Mahomedan empire in India, procured by Colonel Briggs from the library of Tippoo Sultan in 1799; and has been recently referred to at some length

But although the Brahmins, like the priests of Egypt, may have been acquainted with the existence of fossil remains in the strata, it is possible that the doctrine of successive destructions and renovations of the world merely received corroboration from such proofs; and that it may have been originally handed down, like the religious traditions of most nations, from a ruder state of society. The system may have had its source in exaggerated accounts of those partial, but often dreadful, catastrophes, which are sometimes occasioned by particular combinations of natural causes. Floods and volcanic eruptions, the agency of water and fire, are the chief instruments of devastation on our globe. We shall point out in the sequel the extent of many of these calamities, recurring at distant intervals of time, in the present course of nature; and shall only observe here, that they are so peculiarly calculated to inspire a lasting terror, and are so often fatal in their consequences to great multitudes of people, that it scarcely requires the passion for the marvellous, so characteristic of rude and half-civilized nations, still less the exuberant imagination of eastern writers, to augment them into general cataclysms and conflagrations.

The great flood of the Chinese, which their traditions carry back to the period of Yaou, something

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by Dr. Buckland.—(Geol. Trans. 2d Series, vol. ii. part iii. p. 389.)—It is stated that, in the year 762 (or 1360 of our era), the king employed fifty thousand labourers in cutting through a mound, so as to form a junction between the rivers Selima and Sutluj; and in this mound were found the bones of elephants and men, some of them petrified, and some of them resembling bone. The gigantic dimensions attributed to the human bones show them to have belonged to some of the larger pachydermata.

more than 2000 years before our era, has been identified by some persons with the universal deluge described in the Old Testament; but according to Mr. Davis, who accompanied two of our embassies to China, and who has carefully examined their written accounts, the Chinese cataclysm is therein described as interrupting the business of agriculture, rather than as involving a general destruction of the human race. The great Yu was celebrated for having "opened nine channels to draw off the waters," which "covered the low hills and bathed the foot of the highest mountains." Mr. Davis suggests that a great derangement of the waters of the Yellow River, one of the largest in the world, might even now cause the flood of Yaou to be repeated, and lay the most fertile and populous plains of China under water. In modern times the bursting of the banks of an artificial canal, into which a portion of the Yellow River has been turned, has repeatedly given rise to the most dreadful accidents, and is a source of perpetual anxiety to the government. It is easy, therefore, to imagine how much greater may have been the inundation, if this valley was ever convulsed by a violent earthquake.*

Humboldt relates the interesting fact that after the annihilation of a large part of the inhabitants of Cumana, by an earthquake in 1766, a season of extraordinary fertility ensued, in consequence of the great rains which accompanied the subterranean convulsions. "The Indians," he says, "celebrated, after the ideas of an antique superstition, by festivals and

* See Davis on "The Chinese," published by the Soc. for the Diffus. of Use. Know. vol. i. p. 128.

dancing, the destruction of the world and the approaching epoch of its regeneration."*

The existence of such rites among the rude nations of South America is most important, for it shows what effects may be produced by great catastrophes of this nature, recurring at distant intervals of time, on the minds of a barbarous and uncultivated race. The superstitions of a savage tribe are transmitted through all the progressive stages of society, till they exert a powerful influence on the mind of the philosopher. He may find, in the monuments of former changes on the earth's surface, an apparent confirmation of tenets handed down through successive generations, from the rude hunter, whose terrified imagination drew a false picture of those awful visitations of floods and earthquakes, whereby the whole earth as known to him was simultaneously devastated.

Egyptian Cosmogony.— Respecting the cosmogony of the Egyptian priests, we gather much information from writers of the Grecian sects, who borrowed almost all their tenets from Egypt, and amongst others that of the former successive destruction and renovation of the world.† We learn from Plutarch, that this was the theme of one of the hymns of Orpheus, so celebrated in the fabulous ages of Greece. It was brought by him from the banks of the Nile; and we even find in his verses, as in the Indian systems, a definite period assigned for the duration of each successive world.‡ The returns of great catastrophes were determined by the period of the Annus Magnus,

* Humboldt et Bonpland, Voy. Relat. Hist. vol. i. p. 30.

† Prichard's Egypt. Mythol. p. 177.

‡ Plut. de Defectu Oraculorum, cap. 12. Censorinus de Die Natali. See also Prichard's Egypt. Mythol. p. 182.

or great year,—a cycle composed of the revolutions of the sun, moon, and planets, and terminating when these return together to the same sign whence they were supposed at some remote epoch to have set out. The duration of this great cycle was variously estimated. According to Orpheus, it was 120,000 years; according to others, 300,000; and by Cassander it was taken to be 360,000 years.*

We learn particularly from the Timæus of Plato, that the Egyptians believed the world to be subject to occasional conflagrations and deluges, whereby the gods arrested the career of human wickedness, and purified the earth from guilt. After each regeneration, mankind were in a state of virtue and happiness, from which they gradually degenerated again into vice and immorality. From this Egyptian doctrine, the poets derived the fable of the decline from the golden to the iron age. The sect of Stoics adopted most fully the system of catastrophes destined at certain intervals to destroy the world. These they taught were of two kinds;—the Cataclysm, or destruction by deluge, which sweeps away the whole human race, and annihilates all the animal and vegetable productions of nature; and the Ecpyrosis, or conflagration, which dissolves the globe itself. From the Egyptians also they derived the doctrine of the gradual debasement of man from a state of innocence. Towards the termination of each era the gods could no longer bear with the wickedness of men, and a shock of the elements or a deluge overwhelmed them; after which calamity, Astrea again descended on the earth, to renew the golden age.†

The connection between the doctrine of successive

* Prichard's Egypt. Mythol. p. 182. † Ibid. p. 193.

catastrophes and repeated deteriorations in the moral character of the human race, is more intimate and natural than might at first be imagined. For, in a rude state of society, all great calamities are regarded by the people as judgments of God on the wickedness of man. Thus in our own time, the priests persuaded a large part of the population of Chili, and perhaps believed themselves, that the fatal earthquake of 1822 was a sign of the wrath of Heaven for the great political revolution just then consummated in South America. In like manner, in the account given to Solon by the Egyptian priests, of the submersion of the island of Atlantis under the waters of the ocean, after repeated shocks of an earthquake, we find that the event happened when Jupiter had seen the moral depravity of the inhabitants.* Now, when the notion had once gained ground, whether from causes before suggested or not, that the earth had been destroyed by several general catastrophes, it would next be inferred that the human race had been as often destroyed and renovated. And since every extermination was assumed to be penal, it could only be reconciled with divine justice, by the supposition that man, at each successive creation, was regenerated in a state of purity and innocence.

A very large portion of Asia, inhabited by the earliest nations whose traditions have come down to us, has been always subject to tremendous earthquakes. Of the geographical boundaries of these, and their effects, I shall speak in the proper place. Egypt has, for the most part, been exempt from this scourge, and

* Plato's Timæus.

the tradition of catastrophes in that country was perhaps derived from the East.

One extraordinary fiction of the Egyptian mythology was the supposed intervention of a masculo-feminine principle, to which was assigned the development of the embryo world, somewhat in the way of incubation. For the doctrine was, that when the first chaotic mass had been produced, in the form of an egg, by a self-dependent and eternal Being, it required the mysterious functions of this masculo-feminine artificer to reduce the component elements into organized forms.

Although it is scarcely possible to recall to mind this conceit without smiling, it does not seem to differ essentially in principle from some cosmological notions of men of great genius and science in modern Europe. The Egyptian philosophers ventured on the perilous task of seeking from among the processes now going on something analogous to the mode of operation employed by the Author of Nature in the first creation of organized beings, and they compared it to that which governs the birth of new individuals by generation. To suppose that some general rules might be observed in the first origin of created beings, or the first introduction of new species into our system, was not absurd, nor inconsistent with any thing known to us in the economy of the universe. But the hypothesis, that there was any analogy between such laws and those employed in the continual reproduction of species, was purely gratuitous. In like manner, it is not unreasonable, nor derogatory to the attributes of Omnipotence, to imagine that some general laws may be observed in the creation of new worlds; and if man could witness the birth of such worlds, he might reason by induction upon the origin of his own. But in the ab-

sence of such data, an attempt has been made to fancy some analogy between the agents now employed to destroy, renovate, and perpetually vary the earth's surface, and those whereby the first chaotic mass was formed, and brought by supposed nascent energy from the embryo to the habitable state.

By how many shades the elaborate systems, constructed on these principles, may differ from the mysteries of the "Mundane Egg" of Egyptian fable, I shall not inquire. It would, perhaps, be dangerous ground; and some of our contemporaries might not sit as patiently as the Athenian audience, when the fiction of the chaotic egg, engrafted by Orpheus upon their own mythology, was turned into ridicule by Aristophanes. That comedian introduced his birds singing, in a solemn hymn, "How sable-plumaged Night conceived in the boundless bosom of Erebus, and laid an egg, from which, in the revolution of ages, sprung Love, resplendent with golden pinions. Love fecundated the dark-winged chaos, and gave origin to the race of birds." *

Pythagorean Doctrines. — Pythagoras, who resided for more than twenty years in Egypt, and, according to Cicero, had visited the East, and conversed with the Persian philosophers, introduced into his own country, on his return, the doctrine of the gradual deterioration of the human race from an original state of virtue and happiness: but if we are to judge of his theory concerning the destruction and renovation of the earth from the sketch given by Ovid, we must concede it to have been far more philosophical than any known version of the cosmologies of oriental or Egyptian sects.

* Aristophanes, Birds, 694.

Although Pythagoras is introduced by the poet as delivering his doctrine in person, some of the illustrations are derived from natural events which happened after the death of the philosopher. But nothwithstanding these anachronisms, we may regard the account as a true picture of the tenets of the Pythagorean school in the Augustan age; and although perhaps partially modified, it must have contained the substance of the original scheme. Thus considered, it is extremely curious and instructive; for we here find a comprehensive and masterly summary of almost all the great causes of change now in activity on the globe, and these adduced in confirmation of a principle of perpetual and gradual revolution inherent in the nature of our terrestrial system. These doctrines, it is true, are not directly applied to the explanation of geological phenomena; or, in other words, no attempt is made to estimate what may have been in past ages, or what may hereafter be, the aggregate amount of change brought about by such never-ending fluctuations. Had this been the case, we might have been called upon to admire so extraordinary an anticipation with no less interest than astronomers, when they endeavour to divine by what means the Samian philosopher came to the knowledge of the Copernican system.

Let us now examine the celebrated passages to which we have been adverting * : —

" Nothing perishes in this world; but things merely vary and change their form. To be born, means simply that a thing begins to be something different from what it was before; and dying, is ceasing to be the same thing. Yet, although nothing retains long the same

* Ovid's Metamor. lib. 15.

image, the sum of the whole remains constant." These general propositions are then confirmed by a series of examples, all derived from natural appearances, except the first, which refers to the golden age giving place to the age of iron. The illustrations are thus consecutively adduced.

1. Solid land has been converted into sea.

2. Sea has been changed into land. Marine shells lie far distant from the deep, and the anchor has been found on the summit of hills.

3. Valleys have been excavated by running water, and floods have washed down hills into the sea.*

4. Marshes have become dry ground.

5. Dry lands have been changed into stagnant pools.

6. During earthquakes some springs have been closed up, and new ones have broken out. Rivers have deserted their channels, and have been re-born elsewhere; as the Erasinus in Greece, and Mysus in Asia.

7. The waters of some rivers, formerly sweet, have become bitter, as those of the Anigris in Greece, &c.†

8. Islands have become connected with the main land, by the growth of deltas and new deposits, as in the case of Antissa joined to Lesbos, Pharos to Egypt, &c.

9. Peninsulas have been divided from the main land, and have become islands, as Leucadia; and according to tradition Sicily, the sea having carried away the isthmus.

* Eluvie mons est deductus in æquor, v. 267. The meaning of this last verse is somewhat obscure, but, taken with the context, may be supposed to allude to the abrading power of floods, torrents, and rivers.

† The impregnation from new mineral springs, caused by earthquakes in volcanic countries, is, perhaps, here alluded to.

10. Land has been submerged by earthquakes: the Grecian cities of Helice and Buris, for example, are to be seen under the sea, with their walls inclined.

11. Plains have been upheaved into hills by the confined air seeking vent, as at Trœzen in the Peloponnesus.

12. The temperature of some springs varies at different periods. The waters of others are inflammable.*

13. There are streams which have a petrifying power, and convert the substances which they touch into marble.

14. Extraordinary medicinal and deleterious effects are produced by the water of different lakes and springs.†

15. Some rocks and islands, after floating and having been subject to violent movements, have at length become stationary and immoveable, as Delos, and the Cyanean Isles.‡

16. Volcanic vents shift their position; there was a time when Etna was not a burning mountain, and the

* This is probably an allusion to the escape of inflammable gas, like that in the district of Baku, west of the Caspian; at Pietramala, in the Tuscan Apennines; and several other places.

† Many of those described seem fanciful fictions, like the virtues still so commonly attributed to mineral waters.

‡ Raspe, in a learned and judicious essay (De Novis Insulis, cap. 19.), has made it appear extremely probable that all the traditions of certain islands in the Mediterranean having at some former time frequently shifted their positions, and at length become stationary, originated in the great change produced in their form by earthquakes and submarine eruptions, of which there have been modern examples in the new islands raised in the time of history. When the series of convulsions ended, the island was said to become fixed.

time will come when it will cease to burn. Whether it be that some caverns become closed up by the movements of the earth, and others opened, or whether the fuel is finally exhausted, &c. &c.

The various causes of change in the inanimate world having been thus enumerated, the doctrine of equivocal generation is next propounded, as illustrating a corresponding perpetual flux in the animate creation.*

In the Egyptian and Eastern cosmogonies, and in the Greek version of them, no very definite meaning can, in general, be attached to the term "destruction of the world;" for sometimes it would seem almost to imply the annihilation of our planetary system, and at others a mere revolution of the surface of the earth.

Opinions of Aristotle.—From the works now extant of Aristotle, and from the system of Pythagoras, as above exposed, we might certainly infer that these philosophers considered the agents of change now operating in nature, as capable of bringing about in

* It is not inconsistent with the Hindoo mythology to suppose that Pythagoras might have found in the East not only the system of universal and violent catastrophes and periods of repose in endless succession, but also that of periodical revolutions, effected by the continued agency of ordinary causes. For Brahma, Vishnu, and Siva, the first, second, and third persons of the Hindoo triad, severally represented the Creative, the Preserving, and the Destroying powers of the Deity. The co-existence of these three attributes, all in simultaneous operation, might well accord with the notion of perpetual but partial alterations finally bringing about a complete change. But the fiction expressed in the verses before quoted from Menù, of eternal vicissitudes in the vigils and slumbers of the Infinite Being, seems accommodated to the system of great general catastrophes followed by new creations and periods of repose.

the lapse of ages a complete revolution; and the Stagyrite even considers occasional catastrophes, happening at distant intervals of time, as part of the regular and ordinary course of nature. The deluge of Deucalion, he says, affected Greece only, and principally the part called Hellas, and it arose from great inundations of rivers during a rainy winter. But such extraordinary winters, he says, though after a certain period they return, do not always revisit the same places.*

Censorinus quotes it as Aristotle's opinion, that there were general inundations of the globe, and that they alternated with conflagrations; and that the flood constituted the winter of the great year, or astronomical cycle, while the conflagration, or destruction by fire, is the summer or period of greatest heat.† If this passage, as Lipsius supposes, be an amplification, by Censorinus, of what is written in "the Meteorics," it is a gross misrepresentation of the doctrine of the Stagyrite, for the general bearing of his reasoning in that treatise tends clearly in an opposite direction. He refers to many examples of changes now constantly going on, and insists emphatically on the great results which they must produce in the lapse of ages. He instances particular cases of lakes that had dried up, and deserts that had at length become watered by rivers and fertilized. He points to the growth of the Nilotic delta since the time of Homer, to the shallowing of the Palus Mæotis within sixty years from his own time; and although, in the same chapter, he says nothing of earthquakes, yet in others of the same treatise he shows himself not

* Meteor. lib. i. cap. 12. † De Die Nat.

unacquainted with their effects.* He alludes, for example, to the upheaving of one of the Eolian islands previous to a volcanic eruption. "The changes of the earth," he says, "are so slow in comparison to the duration of our lives, that they are overlooked (λανθανει); and the migrations of people after great catastrophes, and their removal to other regions, cause the event to be forgotten." †

When we consider the acquaintance displayed by Aristotle, in his various works, with the destroying and renovating powers of Nature, the introductory and concluding passages of the twelfth chapter of his "Meteorics" are certainly very remarkable. In the first sentence he says, "The distribution of land and sea in particular regions does not endure throughout all time, but it becomes sea in those parts where it was land, and again it becomes land where it was sea; and there is reason for thinking that these changes take place according to a certain system, and within a certain period." The concluding observation is as follows: —"As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations; but there is none to time. So also of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but every thing changes in the course of time."

It seems, then, that the Greeks had not only derived from preceding nations, but had also, in some slight

* Lib. ii. cap. 14, 15, and 16.

† Ibid.

degree, deduced from their own observations, the theory of periodical revolutions in the inorganic world: there is, however, no ground for imagining that they contemplated former changes in the races of animals and plants. Even the fact that marine remains were inclosed in solid rocks, although observed by some, and even made the groundwork of geological speculation, never stimulated the industry or guided the inquiries of naturalists. It is not impossible that the theory of equivocal generation might have engendered some indifference on this subject, and that a belief in the spontaneous production of living beings from the earth or corrupt matter might have caused the organic world to appear so unstable and fluctuating, that phenomena indicative of former changes would not awaken intense curiosity. The Egyptians, it is true, had taught, and the Stoics had repeated, that the earth had once given birth to some monstrous animals, which existed no longer; but the prevailing opinion seems to have been, that after each great catastrophe the same species of animals were created over again. This tenet is implied in a passage of Seneca, where, speaking of a future deluge, he says, "Every animal shall be generated anew, and man free from guilt shall be given to the earth."*

An old Arabian version of the doctrine of the successive revolutions of the globe, translated by Abraham Ecchellensis †, seems to form a singular exception to

* Omne ex integro animal generabitur, dabiturque terris homo inscius scelerum. — Quæst. Nat. iii. c. 29.

† This author was Regius Professor of Syriac and Arabic at Paris, where, in 1685, he published a Latin translation of many Arabian MSS. on different departments of philosophy. This work has always been considered of high authority.

the general rule, for here we find the idea of different genera and species having been created. The Gerbanites, a sect of astronomers who flourished some centuries before the Christian era, taught as follows: —"That after every period of thirty-six thousand four hundred and twenty-five years, there were produced a pair of *every* species of animal, both male and female, from whom animals might be propagated and inhabit this lower world. But when a circulation of the heavenly orbs was completed, which is finished in that space of years, *other genera and species* of animals are propagated, as also of plants and other things, and the first order is destroyed, and so it goes on for ever and ever."*

Theory of Strabo.—As we learn much of the tenets of the Egyptian and oriental schools in the writings of the Greeks, so many speculations of the early Greek

* Gerbanitæ docebant singulos triginta sex mille annos quadringentos, viginti quinque bina ex singulis animalium speciebus produci, marem scilicet ac feminam, ex quibus animalia propagantur, huncque inferiorem incolunt orbem. Absolutâ autem cœlestium orbium circulatione, quæ illo annorum conficitur spatio, iterum alia producuntur animalium genera et species, quemadmodum et plantarum aliarumque rerum, et primus destruitur ordo, sicque in infinitum producitur.—Histor. Orient. Suppl. per Abrahamum Ecchellensum, Syrum Maronitam, cap. 7. et 8. ad calcem Chronici Oriental. Parisiis, e Typ. regia, 1685, fol.

I have given the punctuation as in the Paris edition, there being no comma after quinque; but, at the suggestion of M. de Schlegel, I have referred the number twenty-five to the period of years, and not to the number of pairs of each species created at one time, as I had done in the two first editions. Fortis inferred that twenty-five new *species* only were created at a time; a construction which the passage will not admit. Mém. sur l'Hist. Nat. de l'Italie, vol. i. p. 202.

count for all the phenomena, and he proposes one of his own, the profoundness of which modern geologists are only beginning to appreciate. "It is not," he says, "because the lands covered by seas were originally at different altitudes, that the waters have risen, or subsided, or receded from some parts and inundated others. But the reason is, that the same land is sometimes raised up and sometimes depressed, and the sea also is simultaneously raised and depressed, so that it either overflows or returns into its own place again. We must therefore ascribe the cause to the ground, either to that ground which is under the sea, or to that which becomes flooded by it, but rather to that which lies beneath the sea, for this is more moveable, and, on account of its humidity, can be altered with greater celerity.* *It is proper*," he observes in continuation, "*to derive our explanations from things which are obvious, and in some measure of daily occurrence, such as deluges, earthquakes, and volcanic eruptions* †, *and sudden swellings of the land beneath the sea;* for the last raise up the sea also, and when the same lands subside again, they occasion the sea to be let

* "Quod enim hoc attollitur aut subsidit, et vel inundat quædam loca, vel ab iis recedit, ejus rei causa non est, quod alia aliis sola humiliora sint aut altiora; sed quod idem solum modò attollitur modò deprimitur, simulque etiam modò attollitur modò deprimitur mare: itaque vel exundat vel in suum redit locum."

Posteà, p. 88. "Restat, ut causam adscribamus solo, sive quod mari subest sive quod inundatur; potiùs tamen ei quod mari subest. Hoc enim multò est mobilius, et quod ob humiditatem celeriùs mutari possit." — Strabo, Geog. Edit. Almelov. Amst. 1707. lib. i.

† (*Volcanic eruptions*, eruptiones flatuum, in the original Greek, αναφυσηματα, gaseous eruptions? or *inflations* of land? — ibid., p. 93.)

down. And it is not merely the small, but the large islands also, and not merely the islands, but the continents, which can be lifted up together with the sea; and both large and small tracts may subside, for habitations and cities, like Bure, Bizona, and many others, have been engulphed by earthquakes."

In another place, this learned geographer, in alluding to the tradition that Sicily had been separated by a convulsion from Italy, remarks, that at present the land near the sea in those parts was rarely shaken by earthquakes, since there were now open orifices whereby fire and ignited matters and waters escape; but formerly, when the volcanos of Etna, the Lipari Islands, Ischia, and others, were closed up, the imprisoned fire and wind might have produced far more vehement movements.* The doctrine, therefore, that volcanos are safety-valves, and that the subterranean convulsions are probably most violent when first the volcanic energy shifts itself to a new quarter, is not modern.

We learn from a passage in Strabo †, that it was a dogma of the Gaulish Druids that the universe was immortal, but destined to survive catastrophes both of fire and water. That this doctrine was communicated to them from the East, with much of their learning, cannot be doubted. Cæsar, it will be remembered, says that they made use of Greek letters in arithmetical computations.‡

Pliny.—This philosopher had no theoretical opinions of his own concerning changes of the earth's surface; and in this department, as in others, he restricted himself to the task of a compiler, without reasoning on the

* Strabo, lib. vi. p. 396. † Book iv.
‡ L. vi. ch. xiii.

facts stated by him, or attempting to digest them into regular order. But his enumeration of the new islands which had been formed in the Mediterranean, and of other convulsions, shews that the ancients had not been inattentive observers of the changes which had taken place within the memory of man.

Such, then, appear to have been the opinions entertained before the Christian era, concerning the past revolutions of our globe. Although no particular investigations had been made for the express purpose of interpreting the monuments of ancient changes, they were too obvious to be entirely disregarded; and the observation of the present course of nature presented too many proofs of alterations continually in progress on the earth to allow philosophers to believe that nature was in a state of rest, or that the surface had remained, and would continue to remain, unaltered. But they had never compared attentively the results of the destroying and reproductive operations of modern times with those of remote eras, nor had they ever entertained so much as a conjecture concerning the comparative antiquity of the human race, or of living species of animals and plants, with those belonging to former conditions of the organic world. They had studied the movements and positions of the heavenly bodies with laborious industry, and made some progress in investigating the animal, vegetable, and mineral kingdoms; but the ancient history of the globe was to them a sealed book, and, although written in characters of the most striking and imposing kind, they were unconscious even of its existence.

CHAPTER III.

HISTORY OF THE PROGRESS OF GEOLOGY—*continued.*

Arabian writers of the tenth century — Avicenna — Omar — Cosmogony of the Koran — Kazwini — Early Italian writers (p. 33.)—Fracastoro — Controversy as to the real nature of fossils — Attributed to the Mosaic deluge — Palissy — Steno (p. 39.) — Scilla — Quirini — Boyle — Lister — Leibnitz — Hooke's Theory of Elevation by Earthquakes (p. 46.) — Of lost species of animals — Ray — Physico-theological writers — Woodward's Diluvial Theory (p. 53) — Burnet — Whiston — Vallisneri — Lazzaro Moro (p. 59.) — Generelli — Buffon (p. 67.) — His theory condemned by the Sorbonne as unorthodox — His declaration — Targioni — Arduino — Michell — Catcott — Raspe — Fuchsel (p. 75.) — Fortis — Testa — Whitehurst — Pallas — Saussure.

Arabian writers.—AFTER the decline of the Roman empire, the cultivation of physical science was first revived with some success by the Saracens, about the middle of the eighth century of our era. The works of the most eminent classic writers were purchased at great expense from the Christians, and translated into Arabic; and Al Mamûn, son of the famous Harûn-al-Rashid, the contemporary of Charlemagne, received with marks of distinction, at his court at Bagdad, astronomers and men of learning from different countries. This caliph, and some of his successors, encountered much opposition and jealousy from the doctors of the Mahomedan law, who wished the Moslems to confine their studies to the Koran, dreading the effects of the diffusion of a taste for the physical sciences.*

* Mod. Univ. Hist. vol. ii. chap. iv. section iii.

Avicenna.—Almost all the works of the early Arabian writers are lost. Amongst those of the tenth century, of which fragments are now extant, is a short treatise "On the Formation and Classification of Minerals," by Avicenna, a physician, in whose arrangement there is considerable merit. The second chapter, "On the Cause of Mountains," is remarkable; for mountains, he says, are formed, some by essential, others by accidental causes. In illustration of the essential, he instances "a violent earthquake, by which land is elevated, and becomes a mountain;" of the accidental, the principal, he says, is excavation by water, whereby cavities are produced, and adjoining lands made to stand out and form eminences.*

Omar—Cosmogony of the Koran.—In the same century also, Omar, surnamed "El Aalem," or "The Learned," wrote a work on "The Retreat of the Sea." It appears that on comparing the charts of his own time with those made by the Indian and Persian astronomers two thousand years before, he had satisfied himself that important changes had taken place since the times of history in the form of the coasts of Asia, and that the extension of the sea had been greater at some former periods. He was confirmed in this opinion by the numerous salt springs and marshes in the interior of Asia,—a phenomenon from which Pallas, in more recent times, has drawn the same inference.

Von Hoff has suggested, with great probability, that the changes in the level of the Caspian (some of which there is reason to believe have happened within the

* Montes quandóque fiunt ex causa essentiali, quandóque ex causa accidentali. Ex essentiali causa, ut ex vehementi motu terræ elevatur terra, et fit mons. Accidentali, &c. — De Congelatione Lapidum, ed. Gedani, 1682.

historical era), and the geological appearances in that district, indicating the desertion by that sea of its ancient bed, had probably led Omar to his theory of a general subsidence. But whatever may have been the proofs relied on, his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors; to avoid which persecution he went into voluntary banishment from Samarkand.*

The cosmological opinions expressed in the Koran are few, and merely introduced incidentally: so that it is not easy to understand how they could have interfered so seriously with free discussion on the former changes of the globe. The Prophet declares that the earth was created in two days, and the mountains were then placed on it; and during these, and two additional days, the inhabitants of the earth were formed; and in two more, the seven heavens.† There is no

* Von Hoff, Geschichte der Veränderungen der Erdoberfläche, vol. i. p. 406., who cites Delisle, bey Hismann Welt-und Völkergeschichte. Alte Gesch. 1ter Theil. s. 234. — The Arabian persecutions for heretical dogmas in theology were often very sanguinary. In the same ages wherein learning was most in esteem, the Mahometans were divided into two sects, one of whom maintained that the Koran was increate, and had subsisted in the very essence of God from all eternity; and the other, the Motazalites, who, admitting that the Koran was instituted by God, conceived it to have been first made when revealed to the Prophet at Mecca, and accused their opponents of believing in two eternal beings. The opinions of each of these sects were taken up by different caliphs in succession, and the followers of each sometimes submitted to be beheaded, or flogged till at the point of death, rather than renounce their creed. — Mod. Univ. Hist. vol. ii. ch. iv.

† Koran, chap. xli.

more detail of circumstances; and the deluge, which is also mentioned, is discussed with equal brevity. The waters are represented to have poured out of an oven; a strange fable, said to be borrowed from the Persian Magi, who represented them as issuing from the oven of an old woman.* All men were drowned, save Noah and his family; and then God said, "O earth, swallow up thy waters; and thou, O heaven, withhold thy rain;" and immediately the waters abated.†

We may suppose Omar to have represented the desertion of the land by the sea to have been gradual, and that his hypothesis required a greater lapse of ages than was consistent with Moslem orthodoxy; for it is to be inferred from the Koran, that man and this planet were created at the same time; and although Mahomet did not limit expressly the antiquity of the human race, yet he gave an implied sanction to the Mosaic chronology, by the veneration expressed by him for the Hebrew Patriarchs.‡

A manuscript work, entitled the "Wonders of Nature," is preserved in the Royal Library at Paris, by an Arabian writer, Mohammed Kazwini, who flourished in the seventh century of the Hegira, or at the close of the thirteenth century of our era.§ Besides several curious remarks on aerolites, earthquakes, and the successive changes of position which the land and

* Sale's Koran, chap. xi. see note. † Ibid.

‡ Kossa, appointed master to the Caliph Al Mamûd, was author of a book, entitled "The History of the Patriarchs and Prophets, *from the Creation of the World*."— Mod. Univ. Hist. vol. ii. chap. iv.

§ Translated by MM. Chezy and De Sacy, and cited by M. Elie de Beaumont, Ann. des Sci. Nat. 1832.

sea have undergone, we meet with the following beautiful passage, which is given as the narrative of Khidhz, an allegorical personage: — "I passed one day by a very ancient and wonderfully populous city, and asked one of its inhabitants how long it had been founded. 'It is indeed a mighty city,' replied he, 'we know not how long it has existed, and our ancestors were on this subject as ignorant as ourselves.' Five centuries afterwards, as I passed by the same place, I could not perceive the slightest vestige of the city. I demanded of a peasant who was gathering herbs, upon its former site, how long it had been destroyed. 'In sooth, a strange question!' replied he. 'The ground here has never been different from what you now behold it.'—'Was there not of old,' said I, 'a splendid city here?'—'Never,' answered he, 'so far as we have seen, and never did our fathers speak to us of any such.' On my return there, 500 years afterwards, *I found the sea in the same place*, and on its shores were a party of fishermen, of whom I inquired how long the land had been covered by the waters? 'Is this a question,' said they, 'for a man like you? this spot has always been what it is now.' I again returned, 500 years afterwards, and the sea had disappeared; I inquired of a man who stood alone upon the spot, how long ago this change had taken place, and he gave me the same answer as I had received before. Lastly, on coming back again after an equal lapse of time, I found there a flourishing city, more populous and more rich in beautiful buildings than the city I had seen the first time, and when I would fain have informed myself concerning its origin, the inhabitants answered me, 'Its rise is lost in remote antiquity: we are ignorant

how long it has existed, and our fathers were on this subject as ignorant as ourselves.' "

Early Italian writers—Fracastoro, 1517.—It was not till the earlier part of the sixteenth century that geological phenomena began to attract the attention of the Christian nations. At that period a very animated controversy sprung up in Italy, concerning the true nature and origin of marine shells, and other organized fossils, found abundantly in the strata of the peninsula.* The excavations made in 1517, for repairing the city of Verona, brought to light a multitude of curious petrifactions, and furnished matter for speculation to different authors, and among the rest to Fracastoro †, who declared his opinion, that fossil shells had all belonged to living animals, which had formerly lived and multiplied where their exuviæ are now found. He exposed the absurdity of having recourse to a certain "plastic force," which it was said had power to fashion stones into organic forms; and, with no less cogent arguments, demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory obstinately defended by some. That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. His clear exposition of the evidence would have terminated the discussion for ever, if the passions of mankind had not been enlisted in the

* See Brocchi's Discourse on the Progress of the Study of Fossil Conchology in Italy, where some of the following notices on Italian writers will be found more at large.

† Museum Calceol.

dispute; and even though doubts should for a time have remained in some minds, they would speedily have been removed by the fresh information obtained almost immediately afterwards, respecting the structure of fossil remains, and of their living analogues.

But the clear and philosophical views of Fracastoro were disregarded, and the talent and argumentative powers of the learned were doomed for three centuries to be wasted in the discussion of these two simple and preliminary questions: first, whether fossil remains had ever belonged to living creatures; and, secondly, whether, if this be admitted, all the phenomena could not be explained by the Noachian deluge. It had been the general belief of the Christian world down to the period now under consideration, that the origin of this planet was not more remote than a few thousand years; and that since the creation the deluge was the only great catastrophe by which considerable change had been wrought on the earth's surface. On the other hand, the opinion was scarcely less general, that the final dissolution of our system was an event to be looked for at no distant period. The era, it is true, of the expected millennium had passed away; and for five hundred years after the fatal hour, when the annihilation of the planet had been looked for, the monks remained in undisturbed enjoyment of rich grants of land bequeathed to them by pious donors, who, in the preamble of deeds beginning "appropinquante mundi termino"——"appropinquante magno judicii die," left lasting monuments of the popular delusion.*

* In Sicily, in particular, the title-deeds of many valuable grants of land to the monasteries are headed by such preambles,

But although in the sixteenth century it had become necessary to interpret the prophecies more liberally, and to assign a more distant date to the future conflagration of the world, we find, in the speculations of the early geologists, perpetual allusion to such an approaching catastrophe; while in all that regarded the antiquity of the earth, no modification whatever of the opinions of the dark ages had been effected. Considerable alarm was at first excited when the attempt was made to invalidate, by physical proofs, an article of faith so generally received; but there was sufficient spirit of toleration and candour amongst the Italian ecclesiastics, to allow the subject to be canvassed with much freedom. They even entered warmly into the controversy themselves, often favouring different sides of the question; and however much we may deplore the loss of time and labour devoted to the defence of untenable positions, it must be conceded, that they displayed far less polemic bitterness than certain writers who followed them "beyond the Alps," two centuries and a half later.

CONTROVERSY AS TO THE REAL NATURE OF FOSSIL ORGANIC REMAINS.

Mattioli — Falloppio. — The system of scholastic disputations encouraged in the universities of the middle ages had unfortunately trained men to habits of indefinite argumentation; and they often preferred absurd and extravagant propositions, because greater skill was required to maintain them; the end and

composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

object of these intellectual combats being victory, and not truth. No theory could be so far-fetched or fantastical as not to attract some followers, provided it fell in with popular notions; and as cosmogonists were not at all restricted, in building their systems, to the agency of known causes, the opponents of Fracastoro met his arguments by feigning imaginary causes, which differed from each other rather in name than in substance. Andrea Mattioli, for instance, an eminent botanist, the illustrator of Dioscorides, embraced the notion of Agricola, a German miner, that a certain "materia pinguis," or "fatty matter," set into fermentation by heat, gave birth to fossil organic shapes. Yet Mattioli had come to the conclusion, from his own observations, that porous bodies, such as bones and shells, might be converted into stone, as being permeable to what he termed the "lapidifying juice." In like manner, Falloppio of Padua conceived that petrified shells were generated by fermentation in the spots where they are found, or that they had in some cases acquired their form from "the tumultuous movements of terrestrial exhalations." Although celebrated as a professor of anatomy, he taught that certain tusks of elephants dug up in his time at Puglia were mere earthy concretions; and, consistently with these principles, he even went so far as to consider it probable, that the vases of Monte Testaceo at Rome were natural impressions stamped in the soil.* In the same spirit, Mercati, who published, in 1574, faithful figures of the fossil shells preserved by Pope Sixtus V. in the Museum of the Vatican, expressed an opinion that they were mere stones, which had assumed

* De Fossilib. pp. 109. and 176.

their peculiar configuration from the influence of the heavenly bodies; and Olivi of Cremona, who described the fossil remains of a rich Museum at Verona, was satisfied with considering them as mere "sports of nature."

Some of the fanciful notions of those times were deemed less unreasonable, as being somewhat in harmony with the Aristotelian theory of spontaneous generation, then taught in all the schools. For men who had been taught in early youth, that a large proportion of living animals and plants were formed from the fortuitous concourse of atoms, or had sprung from the corruption of organic matter, might easily persuade themselves, that organic shapes, often imperfectly preserved in the interior of solid rocks, owed their existence to causes equally obscure and mysterious.

Cardano, 1552.—But there were not wanting some who, during the progress of this century, expressed more sound and sober opinions. The title of a work of Cardano's, published in 1552, "De Subtilitate" (corresponding to what would now be called Transcendental Philosophy), would lead us to expect, in the chapter on minerals, many far-fetched theories characteristic of that age; but, when treating of petrified shells, he decided that they clearly indicated the former sojourn of the sea upon the mountains.*

Cesalpino—*Majoli*, 1597.—Cesalpino, a celebrated botanist, conceived that fossil shells had been left on the land by the retiring sea, and had concreted into stone during the consolidation of the soil†; and in the following year (1597), Simeone Majoli‡ went still

* Brocchi, Con. Foss. Subap. Disc. sui Prog. vol. i. p. 5.

† De Metallicis. ‡ Dies Caniculares.

farther; and, coinciding for the most part with the views of Cesalpino, suggested that the shells and submarine matter of the Veronese, and other districts, might have been cast up upon the land by volcanic explosions, like those which gave rise, in 1538, to Monte Nuovo, near Puzzuoli. This hint seems to have been the first imperfect attempt to connect the position of fossil shells with the agency of volcanos, a system afterwards more fully developed by Hooke, Lazzaro Moro, Hutton, and other writers.

Two years afterwards, Imperati advocated the animal origin of fossilized shells, yet admitted that stones could vegetate by force of "an internal principle;" and, as evidence of this, he referred to the teeth of fish, and spines of echini found petrified.*

Palissy, 1580.— Palissy, a French writer on "The Origin of Springs from Rain-water," and of other scientific works, undertook, in 1580, to combat the notions of many of his contemporaries in Italy, that petrified shells had all been deposited by the universal deluge. "He was the first," said Fontenelle, when, in the French Academy, he pronounced his eulogy, nearly a century and a half later, "who dared assert," in Paris, that fossil remains of testacea and fish had once belonged to marine animals.

Fabio Colonna.— To enumerate the multitude of Italian writers, who advanced various hypotheses, all equally fantastical, in the early part of the seventeenth century, would be unprofitably tedious; but Fabio Colonna deserves to be distinguished; for, although he gave way to the dogma, that all fossil remains were to be referred to the Noachian deluge, he resisted the absurd theory of Stelluti, who taught that fossil wood

* Storia Naturale.

and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat; and he pointed out the different states of shells buried in the strata, distinguishing between, first, the mere mould or impression; secondly, the cast or nucleus; and, thirdly, the remains of the shell itself. He had also the merit of being the first to point out, that some of the fossils had belonged to marine, and some to terrestrial, testacea.*

Steno, 1669.—But the most remarkable work of that period was published by Steno, a Dane, once professor of anatomy at Padua, and who afterwards resided many years at the court of the Grand Duke of Tuscany. His treatise bears the quaint title of "De Solido intra Solidum naturaliter contento (1669)," by which the author intended to express, "On Gems, Crystals, and organic petrifactions inclosed within solid Rocks." This work attests the priority of the Italian school in geological research; exemplifying at the same time the powerful obstacles opposed, in that age, to the general reception of enlarged views in the science. It was still a favourite dogma, that the fossil remains of shells and marine creatures were not of animal origin; an opinion adhered to by many from their extreme reluctance to believe, that the earth could have been inhabited by living beings before a great part of the existing mountains were formed. In reference to this controversy, Steno had dissected a shark recently taken from the Mediterranean, and had demonstrated that its teeth and bones were identical with many fossils found in Tuscany. He had also compared the shells discovered in the Italian strata

* Osserv. sugli Animali aquat. e terrest. 1626.

with living species, pointed out their resemblance, and traced the various gradations from shells merely calcined, or which had only lost their animal gluten, to those petrifactions in which there was a perfect substitution of stony matter. In his division of mineral masses, he insisted on the secondary origin of those deposits in which the spoils of animals, or fragments of older rocks were inclosed. He distinguished between marine formations and those of a fluviatile character, the last containing reeds, grasses, or the trunks and branches of trees. He argued in favour of the original horizontality of sedimentary deposits, attributing their present inclined and vertical position sometimes to the escape of subterranean vapours, heaving the crust of the earth from below upwards, and sometimes to the falling in of masses over-lying subterranean cavities.

He declared that he had obtained proof that Tuscany must successively have acquired six distinct configurations, having been twice covered by water, twice laid dry with a level, and twice with an irregular and uneven surface.* He displayed great anxiety to reconcile his new views with Scripture, for which purpose he pointed to certain rocks as having been formed before the existence of animals and plants; selecting unfortunately as examples certain formations of limestone and sandstone in his own country, now known to contain, though sparingly, the remains of animals and plants, — strata which do not even rank as the oldest part of our secondary series. Steno suggested that Moses, when speaking of the loftiest mountains as having been covered by the deluge, meant merely the loftiest of the hills then existing, which may not have been very high.

* Sex itaque distinctas Etruriæ facies agnoscimus, dum bis fluida, bis plana, et sicca, bis aspera fuerit, &c.

The diluvian waters, he supposed, may have issued from the interior of the earth into which they had retired, when in the beginning the land was separated from the sea. These, and other hypotheses on the same subject, are not calculated to enhance the value of the treatise, and could scarcely fail to detract from the authority of those opinions which were sound and legitimate deductions from fact and observation. They have served, nevertheless, as the germs of many popular theories of later times, and in an expanded form have been put forth as original inventions by some of our contemporaries.

Scilla, 1670. — Scilla, a Sicilian painter, published, in 1670, a treatise, in Latin, on the fossils of Calabria, illustrated by good engravings. This work proves the continued ascendency of dogmas often refuted; for we find the wit and eloquence of the author chiefly directed against the obstinate incredulity of naturalists as to the organic nature of fossil shells.* Like many eminent naturalists of his day, Scilla gave way to the popular persuasion, that all fossil shells were the effects and proofs of the Mosaic deluge. It may be doubted whether he was perfectly sincere, and some of his contemporaries who took the same course were certainly not so. But so eager were they to root out what they justly considered an absurd prejudice respecting the nature of organized fossils, that they seem to have been ready to make any concessions, in order to

* Scilla quotes the remark of Cicero on the story that a stone in Chios had been cleft open, and presented the head of Paniscus in relief: — "I believe," said the orator, "that the figure bore some resemblance to Paniscus, but not such that you would have deemed it sculptured by Scopas; for chance never perfectly imitates the truth."

establish this preliminary point. Such a compromising policy was short-sighted, since it was to little purpose that the nature of the documents should at length be correctly understood, if men were to be prevented from deducing fair conclusions from them.

Diluvial Theory.—The theologians who now entered the field in Italy, Germany, France, and England, were innumerable; and henceforward, they who refused to subscribe to the position, that all marine organic remains were proofs of the Mosaic deluge, were exposed to the imputation of disbelieving the whole of the sacred writings. Scarcely any step had been made in approximating to sound theories since the time of Fracastoro, more than a hundred years having been lost, in writing down the dogma that organized fossils were mere sports of nature. An additional period of a century and a half was now destined to be consumed in exploding the hypothesis, that organized fossils had all been buried in the solid strata by the Noachian flood. Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts. In recent times, we may attribute our rapid progress chiefly to the careful determination of the order of succession in mineral masses, by means of their different organic contents, and their regular superposition. But the old diluvialists were induced by their system to confound all the groups of strata together instead of discriminating,—to refer all appearances to one cause and to one brief period, not to a variety of causes acting throughout a long succession of epochs. They saw the phenomena only as they desired to see them, sometimes misrepresenting facts,

and at other times deducing false conclusions from correct data. Under the influence of such prejudices, three centuries were of as little avail as a few years in our own times, when we are no longer required to propel the vessel against the force of an adverse current.

It may be well, therefore, to forewarn the reader, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, he must expect to be occupied with accounts of the retardation, as well as of the advance of the science. It will be necessary to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions; and to dwell on futile reasoning and visionary hypothesis, because some of the most extavagant systems were invented or controverted by men of acknowledged talent. In short, a sketch of the progress of geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to one who studies the philosophy of the human mind, is too often barren of instruction to him who searches for truths in physical science.

Quirini, 1676.—Quirini, in 1676*, contended, in opposition to Scilla, that the diluvian waters could not have conveyed heavy bodies to the summit of mountains, since the agitation of the sea never (as Boyle had demonstrated) extended to great depths †; and

* De Testaceis fossilibus Mus. Septaliani.

† The opinions of Boyle, alluded to by Quirini, were published a few years before, in a short article entitled "On the Bottom of the Sea." From observations collected from the divers of the pearl

still less could the testacea, as some pretended, have lived in these diluvian waters; for "the duration of the flood was brief, and *the heavy rains must have destroyed the saltness of the sea!*" He was the first writer who ventured to maintain that the universality of the Noachian cataclysm ought not to be insisted upon. As to the nature of petrified shells, he conceived that as earthy particles united in the sea to form the shells of mollusca, the same crystallizing process might be effected on the land; and that, in the latter case, the germs of the animals might have been disseminated through the substance of the rocks, and afterwards developed by virtue of humidity. Visionary as was this doctrine, it gained many proselytes even amongst the more sober reasoners of Italy and Germany; for it conceded that the position of fossil bodies could not be accounted for by the diluvial theory.

Plot — Lister, 1678. — In the mean time, the doctrine that fossil shells had never belonged to real animals maintained its ground in England, where the agitation of the question began at a much later period. Dr. Plot, in his "Natural History of Oxfordshire" (1677), attributed to a "plastic virtue latent in the earth" the origin of fossil shells and fishes; and Lister, to his accurate account of British shells, in 1678, added the fossil species, under the appellation of

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fishery, Boyle inferred that, when the waves were six or seven feet high above the surface of the water, there were no signs of agitation at the depth of fifteen fathoms; and that even during heavy gales of wind, the motion of the water was exceedingly diminished at the depth of twelve or fifteen feet. He had also learnt from some of his informants, that there were currents running in opposite directions at different depths. — Boyle's Works, vol. iii. p. 110. London, 1744.

turbinated and bivalve stones. "Either," said he: "these were terriginous, or, if otherwise, the animals they so exactly represent *have become extinct.*" This writer appears to have been the first who was aware of the continuity over large districts of the principal groups of strata in the British series, and who proposed the construction of regular geological maps.*

Leibnitz, 1680. — The great mathematician Leibnitz published his "Protogœa" in 1680. He imagined this planet to have been originally a burning luminous mass, which ever since its creation has been undergoing refrigeration. When the outer crust had cooled down sufficiently to allow the vapours to be condensed, they fell, and formed a universal ocean, covering the loftiest mountains, and investing the whole globe. The crust as it consolidated from a state of fusion, assumed a vesicular and cavernous structure; and being rent in some places, allowed the water to rush into the subterranean hollows, whereby the level of the primeval ocean was lowered. The breaking in of these vast caverns is supposed to have given rise to the dislocated and deranged position of the strata "which Steno had described," and the same disruptions communicated violent movements to the incumbent waters, whence great inundations ensued. The waters, after they had been thus agitated, deposited their sedimentary matter during intervals of quiescence, and hence the various stony and earthy strata. "We may recognize, therefore," says Leibnitz, "a double origin of primitive masses, the one by refrigeration from igneous fusion, the other by concretion from

* See Mr. Conybeare's excellent Introduction to the "Outlines of the Geology of England and Wales," p. 12.

aqueous solution."* By the repetition of similar causes (the disruption of the crust and consequent floods), alternations of new strata were produced, until at length these causes were reduced to a condition of quiescent equilibrium, and a more permanent state of things was established.†

Hooke, 1688. — The "Posthumous Works of Robert Hooke, M.D.," well known as a great mathematician and natural philosopher, appeared in 1705, containing "A Discourse of Earthquakes," which, we are informed by his editor, was written in 1668, but revised at subsequent periods. ‡ Hooke frequently refers to the best Italian and English authors who wrote before his time on geological subjects; but there are no passages in his works implying that he participated in the enlarged views of Steno and Lister, or of his contemporary, Woodward, in regard to the geographical extent of certain groups of strata. His treatise, however, is the most philosophical production of that age, in regard to the causes of former changes in the organic and inorganic kingdoms of nature.

"However trivial a thing," he says, "a rotten shell may appear to some, yet these monuments of nature

* Unde jam duplex origo intelligitur primorum corporum, una, cum ab ignis fusione refrigescerent, altera, cum reconcrescerent ex solutione aquarum.

† Redeunte mox simili causâ strata subinde alia aliis imponerentur, et facies teneri adhuc orbis sæpius novata est. Donec quiescentibus causis, atque æquilibratis, consistentior emergeret rerum status. — For an able analysis of the views of Leibnitz, in his Protogœa, see Mr. Conybeare's Report to the Brit. Assoc. on the Progress of Geological Science, 1832.

‡ Between the year 1688 and his death, in 1703, he read several memoirs to the Royal Society, and delivered lectures on various subjects, relating to fossil remains and the effects of earthquakes.

are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design, as may also books, manuscripts, and inscriptions, as all the learned are now sufficiently satisfied has often been actually practised," &c.; "and though it must be granted that it is very difficult to read them (the records of nature) and *to raise a chronology out of them*, and to state the intervals of the time wherein such or such catastrophes and mutations have happened, yet it is not impossible."*

Respecting the extinction of species, Hooke was aware that the fossil ammonites, nautili, and many other shells and fossil skeletons found in England, were of different species from any then known; but he doubted whether the species had become extinct, observing that the knowledge of naturalists of all the marine species, especially those inhabiting the deep sea, was very deficient. In some parts of his writings, however, he leans to the opinion that species had been lost; and, in speculating on this subject, he even suggests that there might be some connection between the disappearance of certain kinds of animals and plants, and the changes wrought by earthquakes in former ages. Some species, he observes with great sagacity, are "*peculiar to certain places*, and not to be found elsewhere. If, then, such a place had been swallowed up, it is not improbable but that those animate beings may have been destroyed with it; and this may be true both of aërial and aquatic animals: for those animated bodies, whether vegetables or animals, which were naturally nourished or refreshed by the air, would be

* Posth. Works, Lecture, Feb. 29. 1688.

destroyed by the water," &c.* Turtles, he adds, and such large ammonites as are found in Portland, seem to have been the productions of hotter countries; and it is necessary to suppose that England once lay under the sea within the torrid zone! To explain this and similar phenomena, he indulges in a variety of speculations concerning changes in the position of the axis of the earth's rotation, "a shifting of the earth's centre of gravity, analogous to the revolutions of the magnetic pole," &c. None of these conjectures, however, are proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments.

In opposition to the prejudices of his age, we find him arguing against the idea that nature had formed fossil bodies "for no other end than to play the mimic in the mineral kingdom;"—maintaining that figured stones were "really the several bodies they represent, or the mouldings of them petrified," and "not, as some have imagined, 'a lusus naturæ,' sporting herself in the needless formation of useless beings."†

* Posth. Works, p. 327.

† Posth. Works, Lecture, Feb. 15. 1688. Hooke explained, with considerable clearness, the different modes wherein organic substances may become lapidified; and, among other illustrations, he mentions some silicified palm-wood brought from Africa, on which M. de la Hire had read a Memoir to the Royal Academy of France (June, 1692), wherein he had pointed out, not only the tubes running the length of the trunk, but the roots at one extremity. De la Hire, says Hooke, also treated of certain trees found petrified in "the river that passes by Bakan, in the kingdom of *Ava*, and which has for the space of ten leagues the virtue of petrifying wood." It is an interesting fact, that the silicified wood of the Irawadi should have attracted attention more than one hundred years ago. Remarkable discoveries have been recently

It was objected to Hooke, that his doctrine of the extinction of species derogated from the wisdom and power of the Omnipotent Creator; but he answered, that, as individuals die, there may be some termination to the duration of a species; and his opinions, he declared, were not repugnant to Holy Writ: for the Scriptures taught that our system was degenerating, and tending to its final dissolution; "and as, when that shall happen, all the species will be lost, why not some at one time and some at another?"*

But his principal object was to account for the manner in which shells had been conveyed into the higher parts of "the Alps, Apennines, and Pyrenean hills, and the interior of continents in general." These and other appearances, he said, might have been brought about by earthquakes, "which have turned plains into mountains, and mountains into plains, seas into land, and land into seas, made rivers where there were none before, and swallowed up others that formerly were, &c. &c.; and which, since the creation of the world, have wrought many great changes on the superficial parts of the earth, and have been the instruments of placing shells, bones, plants, fishes, and the like, in those places where, with much astonishment, we find them."† This doctrine, it is true, had been laid down in terms almost equally explicit by Strabo, to explain the occurrence of fossil shells in the interior of continents, and to that geographer,

made there of fossil animals and vegetables, by Mr. Crawfurd and Dr. Wallich. — See Geol. Trans. vol. ii. part iii. p. 377. second series. De la Hire cites Father Duchatz, in the second volume of "Observations made in the Indies by the Jesuits."

* Posth. Works, Lecture May 29. 1689. † Posth. Works, p. 312.

and other writers of antiquity, Hooke frequently refers; but the revival and development of the system was an important step in the progress of modern science.

Hooke enumerated all the examples known to him of subterranean disturbance, from "the sad catastrophe of Sodom and Gomorrah" down to the Chilian earthquake of 1646. The elevating of the bottom of the sea, the sinking and submersion of the land, and most of the inequalities of the earth's surface, might, he said, be accounted for by the agency of these subterranean causes. He mentions that the coast near Naples *was raised during the eruption of Monte Nuovo;* and that, in 1591, land rose in the island of St. Michael, during an eruption; and although it would be more difficult, he says, to prove, he does not doubt but that there had been as many earthquakes in the parts of the earth under the ocean, as in the parts of the dry land; in confirmation of which, he mentions the immeasurable depth of the sea near some volcanos. To attest the extent of simultaneous subterranean movements, he refers to an earthquake in the West Indies, in the year 1690, where the space of earth raised, or "struck upwards," by the shock, exceeded, he affirms, the length of the Alps and the Pyrenees.

Hooke's diluvial theory. — As Hooke declared the favourite hypothesis of the day, "that marine fossil bodies were to be referred to Noah's flood," to be wholly untenable, he appears to have felt himself called upon to substitute a diluvial theory of his own, and thus he became involved in countless difficulties and contradictions. "During the great catastrophe," he said, "there might have been a changing of that part which was before dry land into sea by

sinking, and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean, in the interval between the creation and the deluge."* Then follows a disquisition on the separation of the land from the waters, mentioned in Genesis: during which operation some places of the shell of the earth were forced outwards, and others pressed downwards or inwards, &c. His diluvial hypothesis very much resembled that of Steno, and was entirely opposed to the fundamental principles professed by him, that he would explain the former changes of the earth *in a more natural manner* than others had done. When, in despite of this declaration, he required a former "crisis of nature," and taught that earthquakes had become debilitated, and that the Alps, Andes, and other chains, had been lifted up in a few months, he was compelled to assume so rapid a rate of change, that his machinery appeared scarcely less extravagant than that of his most fanciful predecessors. For this reason, perhaps, his whole theory of earthquakes met with undeserved neglect.

Ray, 1692.—One of his contemporaries, the celebrated naturalist, Ray, participated in the same desire to explain geological phenomena, by reference to causes less hypothetical than those usually resorted to.† In his essay on "Chaos and Creation," he proposed a system, agreeing in its outline, and in many of its details, with that of Hooke; but his knowledge of

* Post. Works, p. 410.

† Ray's Physico-theological Discourses were of somewhat later date than Hooke's great work on earthquakes. He speaks of Hooke as one "whom for his learning and deep insight into the mysteries of nature he deservedly honoured."—*On the Deluge*, chap. iv.

natural history enabled him to elucidate the subject with various original observations. Earthquakes, he suggested, might have been the second causes employed at the creation, in separating the land from the waters, and in gathering the waters together into one place. He mentions, like Hooke, the earthquake of 1646, which had violently shaken the Andes for some hundreds of leagues, and made many alterations therein. In assigning a cause for the general deluge, he preferred a change in the earth's centre of gravity to the introduction of earthquakes. Some unknown cause, he said, might have forced the subterranean waters outwards, as was, perhaps, indicated by "the breaking up of the fountains of the great deep."

Ray was one of the first of our writers who enlarged upon the effects of running water upon the land, and of the encroachment of the sea upon the shores. So important did he consider the agency of these causes, that he saw in them an indication of the tendency of our system to its final dissolution; and he wondered why the earth did not proceed more rapidly towards a general submersion beneath the sea, when so much matter was carried down by rivers, or undermined in the sea-cliffs. We perceive clearly from his writings, that the gradual decline of our system, and its future consummation by fire, was held to be as necessary an article of faith by the orthodox, as was the recent origin of our planet. His discourses, like those of Hooke, are highly interesting, as attesting the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity. Ray gave an unequivocal proof of the sincerity of his mind, by sacrificing his preferment in the church, rather than take an oath against the Covenanters, which he could

not reconcile with his conscience. His reputation, moreover, in the scientific world placed him high above the temptation of courting popularity, by pandering to the physico-theological taste of his age. It is, therefore, curious to meet with so many citations from the Christian fathers and prophets in his essays on physical science—to find him in one page proceeding, by the strict rules of induction, to explain the former changes of the globe, and in the next gravely entertaining the question, whether the sun and stars, and the whole heavens shall be annihilated, together with the earth, at the era of the grand conflagration.

Woodward, 1695.—Among the contemporaries of Hooke and Ray, Woodward, a professor of medicine, had acquired the most extensive information respecting the geological structure of the crust of the earth. He had examined many parts of the British strata with minute attention; and his systematic collection of specimens, bequeathed to the University of Cambridge, and still preserved there as arranged by him, shows how far he had advanced in ascertaining the order of superposition. From the great number of facts collected by him, we might have expected his theoretical views to be more sound and enlarged than those of his contemporaries; but in his anxiety to accommodate all observed phenomena to the scriptural account of the Creation and Deluge, he arrived at most erroneous results. He conceived "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid."* In corroboration of these views, he insisted upon the fact, that "marine bodies are lodged in the strata according

* Essay towards a Natural History of the Earth, 1695. Preface.

to the order of their gravity, the heavier shells in stone, the lighter in chalk, and so of the rest." * Ray immediately exposed the unfounded nature of this assertion, remarking truly, that fossil bodies "are often mingled, heavy with light, in the same stratum;" and he even went so far as to say, that Woodward "must have invented the phenomena for the sake of confirming his bold and strange hypothesis †"—a strong expression from the pen of a contemporary.

Burnet, 1690.—At the same time Burnet published his "Theory of the Earth." ‡ The title is most characteristic of the age,—"The Sacred Theory of the Earth; containing an Account of the Original of the Earth, and of all the general Changes which it hath already undergone, or is to undergo, till the Consummation of all Things." Even Milton had scarcely ventured in his poem to indulge his imagination so freely in painting scenes of the Creation and Deluge, Paradise and Chaos. He explained why the primeval earth enjoyed a perpetual spring before the flood! showed how the crust of the globe was fissured by "the sun's rays," so that it burst, and thus the diluvial waters were let loose from a supposed central abyss. Not satisfied with these themes, he derived from the books of the inspired writers, and even from heathen authorities, prophetic views of the future revolutions of the globe, gave a most terrific description of the general conflagration, and proved that a new heaven and a new earth will rise out of a *second chaos*—after which will follow the blessed millennium.

* Essay towards a Natural History of the Earth, 1695. Preface.

† Consequences of the Deluge, p. 165.

‡ First published in Latin, between the years 1680 and 1690.

The reader should be informed, that, according to the opinion of many respectable writers of that age, there was good scriptural ground for presuming that the garden bestowed upon our first parents was not on the earth itself, but above the clouds, in the middle region between our planet and the moon. Burnet approaches with becoming gravity the discussion of so important a topic. He was willing to concede that the geographical position of Paradise was not in Mesopotamia, yet he maintained that it was upon the earth, and in the southern hemisphere, near the equinoctial line. Butler selected this conceit as a fair mark for his satire, when, amongst the numerous accomplishments of Hudibras, he says,—

> He knew the seat of Paradise,
> Could tell in what degree it lies;
> And, as he was disposed, could prove it
> Below the moon, or else above it.

Yet the same monarch, who is said never to have slept without Butler's poem under his pillow, was so great an admirer and patron of Burnet's book, that he ordered it to be translated from the Latin into English. The style of the "Sacred Theory" was eloquent, and the book displayed powers of invention of no ordinary stamp. It was, in fact, a fine historical romance, as Buffon afterwards declared; but it was treated as a work of profound science in the time of its author, and was panegyrized by Addison in a Latin ode, while Steele praised it in the "Spectator." Towards the end of the last century, Warton, in his "Essay on Pope," discovered that Burnet united the faculty of *judgment* with powers of imagination.

Whiston, 1696.—Another production of the same school, and equally characteristic of the time, was that

of Whiston, entitled, "A New Theory of the Earth; wherein the Creation of the World in Six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shewn to be perfectly agreeable to Reason and Philosophy." He was at first a follower of Burnet; but his faith in the infallibility of that writer was shaken by the declared opinion of Newton, that there was every presumption in astronomy against any former change in the inclination of the earth's axis. This was a leading dogma in Burnet's system, though not original, for it was borrowed from an Italian, Alessandro degli Alessandri, who had suggested it in the beginning of the fifteenth century, to account for the former occupation of the present continents by the sea. La Place has since strengthened the arguments of Newton, against the probability of any former revolution of this kind.

The remarkable comet of 1680 was fresh in the memory of every one when Whiston first began his cosmological studies, and the principal novelty of his speculations consisted in attributing the deluge to the near approach to the earth of one of these erratic bodies. Having ascribed an increase of the waters to this source, he adopted Woodward's theory, supposing all stratified deposits to have resulted from the "chaotic sediment of the flood." Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptation, so that the doctrine of the earth having existed long previous to the creation of man might no longer be regarded as unorthodox. He had the art to throw an air of plausibility over the most improbable parts of his theory, and seemed to be proceeding in the most sober manner, and by the aid of mathematical

demonstration, to the establishment of his various propositions. Locke pronounced a panegyric on his theory, commending him for having explained so many wonderful and before inexplicable things. His book, as well as Burnet's, was attacked and refuted by Keill.* Like all who introduced purely hypothetical causes to account for natural phenomena, Whiston retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land—on the condensation of the vapours of their tails into water, and other matters equally edifying.

Hutchinson, 1724.—John Hutchinson, who had been employed by Woodward in making his collection of fossils, published afterwards, in 1724, the first part of his "Moses's Principia," wherein he ridiculed Woodward's hypothesis. He and his numerous followers were accustomed to declaim loudly against human learning; and they maintained that the Hebrew scriptures, when rightly translated, comprised a perfect system of natural philosophy, for which reason they objected to the Newtonian theory of gravitation.

Celsius.—Andrea Celsius, the Swedish astronomer, published about this time his remarks on the gradual diminution of the waters in the Baltic, to which I shall have occasion to advert more particularly in the sequel.

Scheuchzer, 1708.—In Germany, in the mean time, Scheuchzer laboured to prove, in a work entitled "The Complaint of the Fishes" (1708), that the earth had been remodelled at the deluge. Pluche also, in 1732, wrote to the same effect; while Holbach, in 1753, after

* An Examination of Dr. Burnet's Theory, &c. 2d ed. 1734.

considering the various attempts to refer all the ancient formations to the Noachian flood, exposed the inadequacy of this cause.

Italian Geologists — Vallisneri. — I return with pleasure to the geologists of Italy, who preceded, as has been already shown, the naturalists of other countries in their investigations into the ancient history of the earth, and who still maintained a decided pre-eminence. They refuted and ridiculed the physico-theological systems of Burnet, Whiston, and Woodward *; while Vallisneri †, in his comments on the Woodwardian theory, remarked how much the interests of religion, as well as those of sound philosophy, had suffered by perpetually mixing up the sacred writings with questions in physical science. The works of this author were rich in original observations. He attempted the first general sketch of the marine deposits of Italy, their geographical extent, and most characteristic organic remains. In his treatise "On the origin of Springs," he explained their dependence on the order and often on the dislocations of the strata, and reasoned philosophically against the opinions of those who regarded the disordered state of the earth's crust as exhibiting signs of the wrath of God for the sins of man. He found himself under the necessity of contending, in his preliminary chapter, against St. Jerome, and four other principal interpreters of Scripture, besides several professors of divinity, "that springs

* Ramazzini even asserted, that the ideas of Burnet were mainly borrowed from a dialogue of one Patrizio; but Brocchi, after reading that dialogue, assures us, that there was scarcely any other correspondence between these systems, except that both were equally whimsical.

† Dei Corpi Marini, Lettere critiche, &c. 1721.

did not flow by subterranean siphons and cavities from the sea upwards, losing their saltness in the passage," for this theory had been made to rest on the infallible testimony of Holy Writ.

Although reluctant to generalize on the rich materials accumulated in his travels, Vallisneri had been so much struck with the remarkable continuity of the more recent marine strata, from one end of Italy to the other, that he came to the conclusion that the ocean formerly extended over the whole earth, and after abiding there for a long time, had gradually subsided. This opinion, however untenable, was a great step beyond Woodward's diluvian hypothesis, against which Vallisneri, and after him all the Tuscan geologists, uniformly contended, while it was warmly supported by the members of the Institute of Bologna.*

Among others of that day, Spada, a priest of Grezzana, in 1737, wrote to prove that the petrified marine bodies near Verona were not diluvian.† Mattani drew a similar inference from the shells of Volterra and other places: while Costantini, on the other hand, whose observations on the valley of the Brenta and other districts were not without value, undertook to vindicate the truth of the deluge, as also to prove that Italy had been peopled by the descendants of Japhet.‡

Moro, 1740.—Lazzaro Moro, in his work (published in 1740) "On the Marine Bodies which are found in the Mountains§," attempted to apply the theory of earthquake as expounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri.||

* Brocchi, p. 28. † Ibid. p. 33. ‡ Ibid. p. 37.

§ Sui Crostacei ed altri Corpi Marini che si trovano sui Monti.

|| Moro does not cite the works of Hooke and Ray; and al-

His attention was awakened to the elevating power of subterranean forces by a remarkable phenomenon which happened in his own time, and which had also been noticed by Vallisneri in his letters. A new island rose in 1707 from a deep part of the sea near Santorino in the Mediterranean, during continued shocks of an earthquake, and, increasing rapidly in size, grew in less than a month to be half a mile in circumference, and about twenty-five feet above high-water mark. It was soon afterwards covered by volcanic ejections, but, when first examined, it was found to be a white rock, bearing on its surface living oysters and crustacea. In order to ridicule the various theories then in vogue, Moro ingeniously supposes the arrival on this new island of a party of naturalists ignorant of its recent origin. One immediately points to the marine shells, as proofs of the universal deluge; another argues that they demonstrate the former residence of the sea upon the mountains; a third dismisses them as mere *sports of nature;* while a fourth affirms, that they were born and nourished within the rock in ancient caverns, into which salt water had been raised in the shape of vapour by the action of subterranean heat.

Moro pointed with great judgment to the *faults* and dislocations of the strata described by Vallisneri, in the Alps and other chains, in confirmation of his doctrine, that the continents had been heaved up by

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though so many of his views were in accordance with theirs, he was probably ignorant of their writings, for they had not been translated. As he always refers to the Latin edition of Burnet, and a French translation of Woodward, we may presume that he did not read English.

subterranean movements. He objected, on solid grounds, to the hypotheses of Burnet and of Woodward; yet he ventured so far to disregard the protest of Vallisneri, as to undertake the adaptation of every part of his own system to the Mosaic account of the creation. On the third day, he said, the globe was every where covered to the same depth by fresh water; and when it pleased the Supreme Being that the dry land should appear, volcanic explosions broke up the smooth and regular surface of the earth composed of primary rocks. These rose in mountain masses above the waves, and allowed melted metals and salts to ascend through fissures. The sea gradually acquired its saltness from volcanic exhalations, and, while it became more circumscribed in area, increased in depth. Sand and ashes ejected by volcanos were regularly disposed along the bottom of the ocean, and formed the secondary strata, which in their turn were lifted up by earthquakes. We need not follow this author in tracing the progress of the creation of vegetables and animals on the other days of creation; but, upon the whole, it may be remarked, that few of the old cosmological theories had been conceived with so little violation of known analogies.

Generelli's illustrations of Moro, 1749. — The style of Moro was extremely prolix, and, like Hutton, who, at a later period, advanced many of the same views, he stood in need of an illustrator. The Scotch geologist was hardly more fortunate in the advocacy of Playfair, than was Moro in numbering amongst his admirers Cirillo Generelli, who, nine years afterwards, delivered at a sitting of Academicians at Cremona a spirited exposition of his theory. This learned Carmelitan friar does not pretend to have been na original observer,

but he had studied sufficiently to enable him to confirm the opinions of Moro by arguments from other writers; and his selection of the doctrines then best established is so judicious, that a brief abstract of them cannot fail to be acceptable, as illustrating the state of geology in Europe, and in Italy in particular, before the middle of the last century.

The bowels of the earth, says he, have carefully preserved the memorials of past events, and this truth the marine productions so frequent in the hills attest. From the reflections of Lazzaro Moro, we may assure ourselves that these are the effects of earthquakes in past times, which have changed vast spaces of sea into terra firma, and inhabited lands into seas. In this, more than in any other department of physics, are observations and experiments indispensable, and we must diligently consider facts. The land is known, wherever we make excavations, to be composed of different strata or soils placed one above the other, some of sand, some of rock, some of chalk, others of marl, coal, pumice, gypsum, lime, and the rest. These ingredients are sometimes pure, and sometimes confusedly intermixed. Within are often imprisoned different marine fishes, like dried mummies, and more frequently shells, crustacea, corals, plants, &c. not only in Italy, but in France, Germany, England, Africa, Asia, and America; — sometimes in the lowest, sometimes in the loftiest beds of the earth, some upon the mountains, some in deep mines, others near the sea, and others hundreds of miles distant from it. Woodward conjectured that these marine bodies might be found every where; but there are rocks in which none of them occur, as is sufficiently attested by Vallisneri and Marsilli. The remains of fossil ani-

mals consist chiefly of their more solid parts, and the most rocky strata must have been soft when such exuviæ were inclosed in them. Vegetable productions are found in different states of maturity, indicating that they were imbedded in different seasons. Elephants, elks, and other terrestrial quadrupeds, have been found in England and elsewhere, in superficial strata, never covered by the sea. Alternations are rare, yet not without example, of marine strata, and those which contain marshy and terrestrial productions. Marine animals are arranged in the subterraneous beds with admirable order, in distinct groups, oysters here, dentalia or corals there, &c. as now, according to Marsilli *, on the shores of the Adriatic. We must abandon the doctrine, once so popular, which denies that organized fossils were derived from living beings, and we cannot account for their present position by the ancient theory of Strato, nor by that of Leibnitz, nor by the universal deluge, as explained by Woodward and others: "nor is it reasonable to call the Deity capriciously upon the stage, and to make him work miracles for the sake of confirming our preconceived hypotheses."—"I hold in utter abomination, most learned Academicians! those systems which are built with their foundations in the air, and cannot be propped up without a miracle; and I undertake, with the assistance of Moro, to explain to you, how these marine animals were transported into the mountains by natural causes." †

* Saggio fisico intorno alla Storia del Mare, part i. p. 24.

† "Abbomino al sommo qualsivoglia sistema, che sia di pianta fabbricato in aria; massime quando è tale, che non possa sostenersi senza un miracolo," &c. - - De' Crostacei e di altre Produz. del Mare, &c. 1749.

A brief abstract then follows of Moro's theory, by which, says Generelli, we may explain all the phenomena, as Vallisneri so ardently desired, "*without violence, without fictions, without hypotheses, without miracles.*"* The Carmelitan then proceeds to struggle against an obvious objection to Moro's system, considered as a method of explaining the revolutions of the earth, *naturally*. If earthquakes have been the agents of such mighty changes, how does it happen that their effects since the times of history have been so inconsiderable? This same difficulty had, as we have seen, presented itself to Hooke, half a century before, and forced him to resort to a former "crisis of nature:" but Generelli defended his position by shewing how numerous were the accounts of eruptions and earthquakes, of new islands, and of elevations and subsidences of land, and yet how much greater a number of like events must have been unattested and unrecorded during the last six thousand years. He also appealed to Vallisneri as an authority to prove that the mineral masses containing shells bore, upon the whole, but a small proportion to those rocks which were destitute of organic remains; and the latter, says the learned monk, might have been created as they now exist, *in the beginning*.

Generelli then describes the continual waste of mountains and continents, by the action of rivers and torrents, and concludes with these eloquent and original observations:—"Is it possible that this waste should have continued for six thousand, and *perhaps* a greater number of years, and that the mountains should remain so great, unless their ruins have been repaired?

* "Senza violenze, senza finzioni, senza supposti, senza miracoli." De' Crostacei e di altre Produz. del Mare, &c. 1749.

Is it credible that the Author of Nature should have founded the world upon such laws, as that the dry land should for ever be growing smaller, and at last become wholly submerged beneath the waters? Is it credible that, amid so many created things, the mountains alone should daily diminish in number and bulk, without there being any repair of their losses? This would be contrary to that order of Providence which is seen to reign in all other things in the universe. Wherefore I deem it just to conclude, that the same cause which, in the beginning of time, raised mountains from the abyss, has down to the present day, continued to produce others, in order to restore from time to time the losses of all such as sink down in different places, or are rent asunder, or in other way suffer disintegration. If this be admitted, we can easily understand why there should now be found upon many mountains so great a number of crustacea and other marine animals."

In the above extract I have not merely enumerated the opinions and facts which are confirmed by recent observation, suppressing all that has since proved to be erroneous, but have given a faithful abridgment of the entire treatise, with the omission only of Moro's hypothesis, which Generelli adopted, with all its faults and excellencies. The reader will therefore remark, that although this admirable essay embraces so large a portion of the principal objects of geological research, it makes no allusion to the extinction of certain classes of animals; and it is evident that no opinions on this head had, at that time, gained a firm footing in Italy. That Lister and other English naturalists should long before have declared in favour of the loss of species, while Scilla and

most of his countrymen hesitated, was perhaps natural, since the Italian museums were filled with fossil shells belonging to species of which a great portion did actually exist in the Mediterranean; whereas the English collectors could obtain no recent species from such of their own strata as were then explored.

The weakest point in Moro's system consisted in deriving *all* the stratified rocks from volcanic ejections; an absurdity which his opponents took care to expose, especially Vito Amici.* Moro seems to have been misled by his anxious desire to represent the formation of secondary rocks as having occupied an extremely short period, while at the same time he wished to employ known agents in nature. To imagine torrents, rivers, currents, partial floods, and all the operations of moving water, to have gone on exerting an energy many thousand times greater than at present, would have appeared preposterous and incredible, and would have required a hundred violent hypotheses; but we are so unacquainted with the true sources of subterranean disturbances, that their former violence may in theory be multiplied indefinitely, without its being possible to prove the same manifest contradiction or absurdity in the conjecture. For this reason, perhaps, Moro preferred to derive the materials of the strata from volcanic ejections, rather than from transportation by running water.

Marsilli.— Marsilli, whose work is alluded to by Generelli, had been prompted to institute inquiries into the bed of the Adriatic, by discovering, in the territory of Parma, (what Spada had observed near Verona, and Schiavo in Sicily,) that fossil shells were not scat-

* Sui Testacei della Sicilia.

tered through the rocks at random, but disposed in regular order, according to certain genera and species.

Vitaliano Donati, 1750.—But with a view of throwing further light upon these questions, Donati, in 1750, undertook a more extensive investigation of the Adriatic, and discovered, by numerous soundings, that deposits of sand, marl, and tufaceous incrustations, most strictly analogous to those of the Subapennine hills, were in the act of accumulating there. He ascertained that there were no shells in some of the submarine tracts, while in other places they lived together in families, particularly the genera Arca, Pecten, Venus, Murex, and some others. He also states that in divers localities he found a mass composed of corals, shells, and crustaceous bodies of different species, confusedly blended with earth, sand, and gravel. At the depth of a foot or more, the organic substances were entirely petrified and reduced to marble; at less than a foot from the surface, they approached nearer to their natural state; while at the surface they were alive, or if dead, in a good state of preservation.

Baldassari.—A contemporary naturalist, Baldassari, had shewn that the organic remains in the tertiary marls of the Siennese territory were grouped in families, in a manner precisely similar to that above alluded to by Donati.

Buffon, 1749.—Buffon first made known his theoretical views concerning the former changes of the earth, in his Natural History, published in 1749. He adopted the theory of an original volcanic nucleus, together with the universal ocean of Leibnitz. By this aqueous envelope the highest mountains were once covered. Marine currents then acted violently, and formed horizontal strata, by washing away solid matter

in some parts, and depositing it in others; they also excavated deep submarine valleys. The level of the ocean was then depressed by the entrance of a part of its waters into subterranean caverns, and thus some land was left dry. Buffon seems not to have profited, like Leibnitz and Moro, by the observations of Steno, or he could not have imagined that the strata were generally horizontal, and that those which contain organic remains had never been disturbed since the era of their formation. He was conscious of the great power annually exerted by rivers and marine currents in transporting earthy materials to lower levels, and he even contemplated the period when they would destroy all the present continents. Although in geology he was not an original observer, his genius enabled him to render his hypothesis attractive; and by the eloquence of his style, and the boldness of his speculations, he awakened curiosity, and provoked a spirit of inquiry amongst his countrymen.

Soon after the publication of his "Natural History," in which was included his "Theory of the Earth," he received an official letter (dated January, 1751) from the Sorbonne, or Faculty of Theology in Paris, informing him that fourteen propositions in his works "were reprehensible, and contrary to the creed of the church." The first of these obnoxious passages, and the only one relating to geology, was as follows: — "The waters of the sea have produced the mountains and valleys of the land — the waters of the heavens, reducing all to a level, will at last deliver the whole land over to the sea, and the sea, successively prevailing over the land, will leave dry new continents like those which we inhabit." Buffon was invited by the College, in very courteous terms, to send in an explanation, or rather a recantation,

of his unorthodox opinions. To this he submitted; and a general assembly of the Faculty having approved of his "Declaration," he was required to publish it in his next work. The document begins with these words;—"I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and *I abandon every thing in my book respecting the formation of the earth*, and, generally, all which may be contrary to the narration of Moses."*

The grand principle which Buffon was called upon to renounce was simply this,—"that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will in time destroy all the continents, hills, and valleys, and reproduce others like them." Now, whatever may be the defects of many of his views, it is no longer controverted that the present continents are of secondary origin. The doctrine is as firmly established as the earth's rotation on its axis; and that the land now elevated above the level of the sea will not endure for ever, is an opinion which gains ground daily, in proportion as we enlarge our experience of the changes now in progress.

Targioni, 1751.—Targioni, in his voluminous "Travels in Tuscany, 1751 and 1754," laboured to fill up the sketch of the geology of that region left by Steno sixty years before. Notwithstanding a want of arrangement and condensation in his memoirs, they contained a rich store of faithful observations. He has not indulged in many general views, but in regard to the origin of valleys, he was opposed to the theory of Buffon, who attributed them principally to submarine

* Hist. Nat. tom. v. éd. de l'Imp. Royale, Paris, 1769.

currents. The Tuscan naturalist laboured to shew that both the larger and smaller valleys of the Apennines were excavated by rivers and floods, caused by the bursting of the barriers of lakes, after the retreat of the ocean. He also maintained that the elephants and other quadrupeds, so frequent in the lacustrine and alluvial deposits of Italy, had inhabited that peninsula; and had not been transported thither, as some had conceived, by Hannibal or the Romans, nor by what they were pleased to term "a catastrophe of nature."

Lehman, 1756.—In the year 1756 the treatise of Lehman, a German mineralogist, and director of the Prussian mines, appeared, who also divided mountains into three classes: the first, those formed with the world, and prior to the creation of animals, and which contained no fragments of other rocks; the second class, those which resulted from the partial destruction of the primary rocks by a general revolution; and a third class, resulting from local revolutions, and in part from the Noachian deluge.*

A French translation of this work appeared in 1759, in the preface of which the translator displays very enlightened views respecting the operations of earthquakes, as well as of the aqueous causes.

Gesner, 1758.—In this year Gesner, the botanist, of Zurich, published an excellent treatise on petrifactions, and the changes of the earth which they testify.† After a detailed enumeration of the various classes of fossils of the animal and vegetable kingdoms, and remarks on the different states in which they are found petrified, he considers the geological phenomena con-

* Essai d'une Hist. Nat. des Couches de la Terre, 1759.

† John Gesner published at Leyden, in Latin.

nected with them; observing, that some, like those of Œningen, resembled the testacea, fish, and plants indigenous in the neighbouring region *; while some, such as ammonites, gryphites, belemnites, and other shells, are either of unknown species, or found only in the Indian and other distant seas. In order to elucidate the structure of the earth, he gives sections, from Verenius, Buffon, and others, obtained in digging wells; distinguishes between horizontal and inclined strata; and, in speculating on the causes of these appearances, mentions Donati's examination of the bed of the Adriatic; the filling up of lakes and seas by sediment; the imbedding of shells, now in progress; and many known effects of earthquakes, such as the sinking down of districts, or the heaving up of the bed of the sea, so as to form new islands and lay dry strata containing petrifactions. The ocean, he says, deserts its shores in many countries, as on the borders of the Baltic; but the rate of recession has been so slow in the last 2000 years, that to allow the Apennines, whose summits are filled with marine shells, to emerge to their present height, would have required about 80,000 years,—a lapse of time ten times greater, or more, than the age of the universe. We must therefore refer the phenomenon to the command of the Deity, related by Moses, that "the waters should be gathered together in one place, and the dry land appear." Gesner adopted the views of Leibnitz, to account for the retreat of the primeval ocean: his essay displays much erudition; and the opinions of preceding writers of Italy, Germany, and England are commented upon with fairness and discrimination.

Arduino, 1759.—In the year following, Arduino †, in

* Part ii. chap. 9.

† Giornale del Griselini, 1759.

his memoirs on the mountains of Padua, Vicenza, and Verona, deduced, from original observations, the distinction of rocks into primary, secondary, and tertiary, and shewed that in those districts there had been a succession of submarine volcanic eruptions.

Michell, 1760.—In the following year (1760) the Rev. John Michell, Woodwardian Professor of Mineralogy at Cambridge, published, in the Philosophical Transactions, an Essay on the Cause and Phenomena of Earthquakes.* His attention had been drawn to this subject by the great earthquake of Lisbon in 1755. He advanced many original and philosophical views respecting the propagation of subterranean movements, and the caverns and fissures wherein steam might be generated. In order to point out the application of his theory to the structure of the globe, he was led to describe the arrangement and disturbance of the strata, their usual horizontality in low countries, and their contortions and fractured state in the neighbourhood of mountain chains. He also explained, with surprising accuracy, the relations of the central ridges of older rocks to the "long narrow slips of similar earths, stones, and minerals," which are parallel to these ridges. In his generalizations, derived in great part from his own observations on the geological

* See a Sketch of the History of English Geology, by Dr. Fitton, in Edinb. Rev. Feb. 1818, re-edited Lond. and Edinb. Phil. Mag. vol. i. and ii. 1832–33. Some of Michell's Observations anticipate in so remarkable a manner the theories established forty years afterwards, that his writings would probably have formed an era in the science, if his researches had been uninterrupted. He held, however, his professorship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

structure of Yorkshire, he anticipated many of the views more fully developed by later naturalists.

Catcott, 1761.—Michell's papers were entirely free from all physico-theological disquisitions, but some of his contemporaries were still earnestly engaged in defending or impugning the Woodwardian hypothesis. We find many of these writings referred to by Catcott, an Hutchinsonian, who published a "Treatise on the Deluge" in 1761. He laboured particularly to refute an explanation offered by his contemporary, Bishop Clayton, of the Mosaic writings. That prelate had declared that the deluge "could not be literally true, save in respect to that part where Noah lived before the flood." Catcott insisted on the universality of the deluge, and referred to traditions of inundations mentioned by ancient writers, or by travellers in the East Indies, China, South America, and other countries. This part of his book is valuable, although it is not easy to see what bearing the traditions have, if admitted to be authentic, on the Bishop's argument; since no evidence is adduced to prove that the catastrophes were contemporaneous events, while some of them are expressly represented by ancient authors to have occurred in succession.

Fortis—Odoardi, 1761.—The doctrines of Arduino, above adverted to, were afterwards confirmed by Fortis and Desmarest, in their travels in the same country; and they, as well as Baldassari, laboured to complete the history of the Subapennine strata. In the work of Odoardi *, there was also a clear argument in favour of the distinct ages of the older Apennine strata, and the Subapennine formations of more recent

* Sui Corpi Marini del Feltrino, 1761.

origin. He pointed out that the strata of these two groups were *unconformable*, and must have been the deposits of different seas at distant periods of time.

Raspe, 1763. — A history of the new islands by Raspe, an Hanoverian, appeared in 1763, in Latin.* In this work, all the authentic accounts of earthquakes which had produced permanent changes on the solid parts of the earth were collected together and examined with judicious criticism. The best systems which had been proposed concerning the ancient history of the globe, both by ancient and modern writers, are reviewed; and the merits and defects of the doctrines of Hooke, Ray, Moro, Buffon, and others, fairly estimated. Great admiration is expressed for the hypothesis of Hooke, and his explanation of the origin of the strata is shown to have been more correct than Moro's, while their theory of the effects of earthquakes was the same. Raspe had not seen Michell's memoir, and his views concerning the geological structure of the earth were perhaps less enlarged; yet he was able to add many additional arguments in favour of Hooke's theory, and to render it, as he said, a nearer approach to what Hooke would have written had he lived in later times. As to the periods wherein all the earthquakes happened, to which we owe the elevation of various parts of our continents and islands, Raspe says he pretends not to assign their duration, still less to defend Hooke's suggestion, that the convulsions almost all took place during the deluge of Noah. He adverts to the apparent indications of the former tropical heat of the climate of Europe, and

* De Novis e Mari Natis Insulis. Raspe was also the editor of the "Philosophical Works of Leibnitz. Amst. et Leipzig, 1765;" also author of "Tassie's Gems," and "Baron Munchausen's Travels."

the changes in the species of animals and plants, as among the most obscure and difficult problems in geology. In regard to the islands raised from the sea, within the times of history or tradition, he declares that some of them were composed of strata containing organic remains, and that they were not, as Buffon had asserted, made of mere volcanic matter. His work concludes with an eloquent exhortation to naturalists to examine the isles which rose, in 1707, in the Grecian Archipelago, and, in 1720, in the Azores, and not to neglect such splendid opportunities of studying nature "in the act of parturition." That Hooke's writings should have been neglected for more than half a century, was matter of astonishment to Raspe; but it is still more wonderful that his own luminous exposition of that theory should, for more than another half century, have excited so little interest.

Fuchsel, 1762 and 1773. — Fuchsel, a German physician, published, in 1762, a geological description of the country between the Thuringerwald and the Hartz, and a memoir on the environs of Rudelstadt*; and afterwards, in 1773, a theoretical work on the ancient history of the earth and of man.† He had evidently advanced considerably beyond his predecessor Lehman, and was aware of the distinctness, both as to position and fossil contents, of several groups of strata of different ages, corresponding to the secondary formations now recognized by geologists in various parts of Germany. He supposed the European continents to have remained covered by the sea until the formation

* Acta Academiæ Electoralis Maguntinæ, vol. ii. Erfurt.

† This account of Fuchsel is derived from an excellent analysis of his memoirs by M. Keferstein. Journ. de Géologie, tom. ii. Oct. 1830.

of the marine strata called in Germany "muschelkalk," at the same time that the terrestrial plants of many European deposits attested the existence of dry land which bordered the ancient sea; land which, therefore, must have occupied the place of the present ocean. This pre-existing continent had been *gradually* swallowed up by the sea, different parts having subsided in succession into subterranean caverns. All the sedimentary strata were originally horizontal, and their present state of derangement must be referred to subsequent oscillations of the ground.

As there were plants and animals in the ancient periods, so also there must have been men, but they did not all descend from one pair, but were created at various points on the earth's surface; and the number of these distinct birth-places was as great as are the original languages of nations.

In the writings of Fuchsel we see a strong desire manifested to explain geological phenomena as far as possible by reference to the agency of known causes; and although some of his speculations were fanciful, his views coincide much more nearly with those now generally adopted, than the theories afterwards promulgated by Werner and his followers.

Brander, 1766.—Gustavus Brander published, in 1766, his "Fossilia Hantoniensia," containing excellent figures of fossil shells from the more modern marine strata of our island. "Various opinions," he says in the preface, "had been entertained concerning the time when and how these bodies became deposited. Some there are, who conceive that it might have been effected in a wonderful length of time by a gradual changing and shifting of the sea," &c. But the most common cause assigned is that of "the deluge." This conjecture, he says, even if the universality of the flood

be not called in question, is purely hypothetical. In his opinion, fossil animals and testacea were, for the most part, of unknown species; and of such as were known, the living analogues now belonged to southern latitudes.

Soldani, 1780.—Soldani applied successfully his knowledge of zoology to illustrate the history of stratified masses. He explained that microscopic testacea and zoophytes inhabited the depths of the Mediterranean; and that the fossil species were, in like manner, found in those deposits wherein the fineness of their particles, and the absence of pebbles, implied that they were accumulated in a deep sea, or far from shore. This author first remarked the alternation of marine and fresh-water strata in the Paris basin.*

Fortis—Testa, 1793.—A lively controversy arose between Fortis and another Italian naturalist, Testa, concerning the fish of Monte Bolca, in 1793. Their letters†, written with great spirit and elegance, show that they were aware that a large proportion of the Subapennine shells were identical with living species, and some of them with species now living in the torrid zone. Fortis proposed a somewhat fanciful conjecture, that when the volcanos of the Vicentin were burning, the waters of the Adriatic had a higher temperature; and in this manner, he said, the shells of warmer regions may once have peopled their own seas. But Testa was disposed to think that these species of testacea were still common to their own and to equinoctial seas: for many, he said, once supposed to be confined to hotter regions, had been afterwards discovered in the Mediterranean.‡

* Saggio orittografico, &c. 1780, and other Works.

† Lett. sui Pesci Fossili di Bolca. Milan, 1793.

‡ This argument of Testa has been strengthened of late years by

Cortesi—Spallanzani—Wallerius—Whitehurst.—While these Italian naturalists, together with Cortesi and Spallanzani, were busily engaged in pointing out the analogy between the deposits of modern and ancient seas, and the habits and arrangement of their organic inhabitants, and while some progress was making, in the same country, in investigating the ancient and modern volcanic rocks, some of the most original observers among the English and German writers, Whitehurst* and Wallerius, were wasting their strength in contending, according to the old Woodwardian hypothesis, that all the strata were formed by the Noachian deluge. But Whitehurst's description of the rocks of Derbyshire was most faithful; and he atoned for false theoretical views, by providing data for their refutation.

Pallas—Saussure.—Towards the close of the eighteenth century, the idea of distinguishing the mineral masses on our globe into separate groups, and studying their relations, began to be generally diffused. Pallas and Saussure were among the most celebrated whose labours contributed to this end. After an attentive examination of the two great mountain chains

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the discovery, that dealers in shells had long been in the habit of selling Mediterranean species as shells of more southern and distant latitudes, for the sake of enhancing their price. It appears, moreover, from several hundred experiments made by that distinguished hydrographer, Captain Smyth, on the water within eight fathoms of the surface, that the temperature of the Mediterranean is on an average $3\frac{1}{2}°$ of Fahrenheit higher than the western part of the Atlantic ocean; an important fact, which in some degree may help to explain why many species are common to tropical latitudes and to the Mediterranean.

* Inquiry into the Original State and Formation of the Earth. 1778.

of Siberia, Pallas announced the result, that the granitic rocks were in the middle, the schistose at their sides, and the limestones again on the outside of these; and this he conceived would prove a general law in the formation of all chains composed chiefly of primary rocks.*

In his "Travels in Russia," in 1793 and 1794, he made many geological observations on the recent strata near the Wolga and the Caspian, and adduced proofs of the greater extent of the latter sea at no distant era in the earth's history. His memoir on the fossil bones of Siberia attracted attention to some of the most remarkable phenomena in geology. He stated that he had found a rhinoceros entire in the frozen soil, with its skin and flesh: an elephant, found afterwards in a mass of ice on the shore of the North sea, removed all doubt as to the accuracy of so wonderful a discovery.†

The subjects relating to natural history which engaged the attention of Pallas were too multifarious to admit of his devoting a large share of his labours exclusively to geology. Saussure, on the other hand, employed the chief portion of his time in studying the structure of the Alps and Jura, and he provided valuable data for those who followed him. He did not pretend to deduce any general system from his numerous and interesting observations; and the few theoretical opinions which escaped from him, seem, like those of Pallas, to have been chiefly derived from the cosmological speculations of preceding writers.

* Observ. on the Formation of Mountains. Act. Petrop. ann. 1778, part i.

† Nov. comm. Petr. XVII. Cuvier, E'loge de Pallas.

CHAPTER IV.

HISTORY OF THE PROGRESS OF GEOLOGY—*continued.*

Werner's Application of Geology to the Art of Mining — Excursive Character of his Lectures — Enthusiam of his Pupils — His Authority —His theoretical Errors—Desmarest's Map and Description of Auvergne (p. 85.) — Controversy between the Vulcanists and Neptunists — Intemperance of the rival Sects — Hutton's Theory of the Earth — His Discovery of Granite Veins (p. 90.) — Originality of his Views — Why opposed — Playfair's Illustrations — Influence of Voltaire's Writings on Geology (p. 95.) — Imputations cast on the Huttonians by Williams, Kirwan, and De Luc — Smith's Map of England (p. 101.) — Geòlogical Society of London — Progress of the Science in France — Growing Importance of the Study of Organic Remains.

Werner.—The art of mining has long been taught in France, Germany, and Hungary, in scientific institutions established for that purpose, where mineralogy has always been a principal branch of instruction.*

Werner was named, in 1775, professor of that science in the " School of Mines," at Freyberg, in Saxony. He directed his attention not merely to the composition and external characters of minerals, but also to what he termed " geognosy," or the natural position of

* Our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any " school of mines," to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner. — See " Prospectus of a School of Mines in Cornwall, by J. Taylor, 1825."

minerals in particular rocks, together with the grouping of those rocks, their geographical distribution, and various relations. The phenomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion: but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically. Werner's mind was at once imaginative and richly stored with miscellaneous knowledge. He associated every thing with his favourite science, and in his excursive lectures he pointed out all the economical uses of minerals, and their application to medicine: the influence of the mineral composition of rocks upon the soil, and of the soil upon the resources, wealth, and civilization of man. The vast sandy plains of Tartary and Africa, he would say, retained their inhabitants in the shape of wandering shepherds; the granitic mountains and the low calcareous and alluvial plains gave rise to different manners, degrees of wealth and intelligence. The history even of languages, and the migrations of tribes, had been determined by the direction of particular strata. The qualities of certain stones used in building would lead him to descant on the architecture of different ages and nations; and the physical geography of a country frequently invited him to treat of military tactics. The charm of his manners and his eloquence kindled enthusiasm in the minds of his pupils; and many, who had intended at first only to acquire a slight knowledge of mineralogy, when they had once heard him, devoted themselves to it as the business of their lives. In a few years, a small

school of mines, before unheard of in Europe, was raised to the rank of a great university; and men already distinguished in science studied the German language, and came from the most distant countries to hear the great oracle of geology.*

Werner had a great antipathy to the mechanical labour of writing, and he could never be persuaded to pen more than a few brief memoirs, and those containing no development of his general views. Although the natural modesty of his disposition was excessive, approaching even to timidity, he indulged in the most bold and sweeping generalizations, and he inspired all his scholars with a most implicit faith in his doctrines. Their admiration of his genius, and the feelings of gratitude and friendship which they all felt for him, were not undeserved; but the supreme authority usurped by him over the opinions of his contemporaries, was eventually prejudicial to the progress of the science; so much so, as greatly to counterbalance the advantages which it derived from his exertions. If it be true that delivery be the first, second, and third requisite in a popular orator, it is no less certain that to travel is of first, second, and third importance to those who desire to originate just and comprehensive views concerning the structure of our globe. Now Werner had not travelled to distant countries; he had merely explored a small portion of Germany, and conceived, and persuaded others believe, that the whole surface of our planet, and all the mountain chains in the world, were made after the model of his own province. It became a ruling object of ambition in the minds of his pupils to confirm the generalizations of their great master, and to discover

* Cuvier, Eloge de Werner.

in the most distant parts of the globe his "universal formations," which he supposed had been each in succession simultaneously precipitated over the whole earth from a common menstruum, or "chaotic fluid." It now appears that the Saxon professor had misinterpreted many of the most important appearances even in the immediate neighbourhood of Freyberg. Thus, for example, within a day's journey of his school, the porphyry, called by him primitive, has been found not only to send forth veins or dikes through strata of the coal formation, but to overlie them in mass. The granite of the Hartz mountains, on the other hand, which he supposed to be the nucleus of the chain, is now well known to traverse and breach the other beds, penetrating even into the plain (as near Goslar); and still nearer Freyberg, in the Erzgebirge, the mica slate does not mantle round the granite, as was supposed, but abuts abruptly against it. Fragments, also, of the greywacke slate, containing organic remains, have recently been found entangled in the granite of the Hartz, by M. de Seckendorf.*

The principal merit of Werner's system of instruction consisted in steadily directing the attention of his scholars to the constant relations of superposition of certain mineral groups; but he had been anticipated, as has been shown in the last chapter, in the discovery of this general law, by several geologists in Italy and elsewhere; and his leading divisions of the secondary strata were, at the same time, and independently, made the basis of an arrangement of the British strata by

* I am indebted for this information partly to Messrs. Sedgwick and Murchison, who have investigated the country, and partly to Dr. Hartmann of Blankenburg, the translator of this work into German.

our countryman, William Smith, to whose work I shall presently return.

Controversy between the Vulcanists and Neptunists.—In regard to basalt and other igneous rocks, Werner's theory was original, but it was also extremely erroneous. The basalts of Saxony and Hesse, to which his observations were chiefly confined, consisted of tabular masses capping the hills, and not connected with the levels of existing valleys, like many in Auvergne and the Vivarais. These basalts, and all other rocks of the same family in other countries, were, according to him, chemical precipitates from water. He denied that they were the products of submarine volcanos; and even taught that, in the primeval ages of the world, there were no volcanos. His theory was opposed, in a twofold sense, to the doctrine of the permanent agency of the same causes in nature; for not only did he introduce, without scruple, many imaginary causes supposed to have once effected great revolutions in the earth, and then to have become extinct, but new ones also were feigned to have come into play in modern times; and, above all, that most violent instrument of change, the agency of subterranean fire.

So early as 1768, before Werner had commenced his mineralogical studies, Raspe had truly characterized the basalts of Hesse as of igneous origin. Arduino, as we have already seen, had pointed out numerous varieties of trap-rock in the Vicentin as analogous to volcanic products, and as distinctly referrible to ancient submarine eruptions. Desmarest, as before stated, had, in company with Fortis, examined the Vicentin in 1766, and confirmed Arduino's views. In 1772, Banks, Solander, and Troil compared the columnar basalt of Hecla with that of the Hebrides.

Collini, in 1774, recognized the true nature of the igneous rocks on the Rhine, between Andernach and Bonn. In 1775, Guettard visited the Vivarais, and established the relation of basaltic currents to lavas. Lastly, in 1779, Faujas published his description of the volcanos of the Vivarais and Velay, and showed how the streams of basalt had poured out from craters which still remain in a perfect state.*

Desmarest. — When sound opinions had thus for twenty years prevailed in Europe concerning the true nature of the ancient trap-rocks, Werner by his simple dictum caused a retrograde movement, and not only overturned the true theory, but substituted for it one of the most unphilosophical that can well be imagined. The continued ascendancy of his dogmas on this subject was the more astonishing, because a variety of new and striking facts were daily accumulated in favour of the correct opinions previously entertained. Desmarest, after a careful examination of Auvergne, pointed out, first, the most recent volcanos which had their craters still entire, and their streams of lava conforming to the level of the present river-courses. He then showed that there were others of an intermediate epoch, whose craters were nearly effaced, and whose lavas were less intimately connected with the present valleys; and, lastly, that there were volcanic rocks, still more ancient, without any discernible craters or scoriæ, and bearing the closest analogy to rocks in other parts of Europe, the igneous origin of which was denied by the school of Freyberg.†

* Cuvier, Eloge de Desmarest.

† Journ. de Phys. vol. xiii. p. 115.; and Mém. de l'Inst., Sciences Mathémat. et Phys. vol. vi. p. 219.

Desmarest's map of Auvergne was a work of uncommon merit. He first made a trigonometrical survey of the district, and delineated its physical geography with minute accuracy and admirable graphic power. He contrived, at the same time, to express, without the aid of colours, a vast quantity of geological detail, the different ages, and sometimes even the structure, of the volcanic rocks, distinguishing them from the fresh-water and the granitic. They alone who have carefully studied Auvergne, and traced the different lava-streams from their craters to their termination,—the various isolated basaltic cappings,—the relation of some lavas to the present valleys,—the absence of such relations in others,—can appreciate the extraordinary fidelity of this elaborate work. No other district of equal dimensions in Europe exhibits, perhaps, so beautiful and varied a series of phenomena; and, fortunately, Desmarest possessed at once the mathematical knowledge required for the construction of a map, skill in mineralogy, and a power of original generalization.

Dolomieu—Montlosier.—Dolomieu, another of Werner's contemporaries, had found prismatic basalt among the ancient lavas of Etna; and, in 1784, had observed the alternations of submarine lavas and calcareous strata in the Val di Noto, in Sicily.* In 1790, also, he described similar phenomena in the Vicentin and in the Tyrol.† Montlosier published, in 1788, an essay on the theory of the volcanos of Auvergne, combining accurate local observations with comprehensive views. Notwithstanding this mass of evidence, the scholars of

* Journ. de Phys. tom. xxv. p. 191.

† Ib. tom. xxxvii. part ii. p. 200.

Werner were prepared to support his opinions to their utmost extent; maintaining, in the fulness of their faith, that even obsidian was an aqueous precipitate. As they were blinded by their veneration for the great teacher, they were impatient of opposition, and soon imbibed the spirit of a faction; and their opponents, the Vulcanists, were not long in becoming contaminated with the same intemperate zeal. Ridicule and irony were weapons more frequently employed than argument by the rival sects, till at last the controversy was carried on with a degree of bitterness almost unprecedented in questions of physical science. Desmarest alone, who had long before provided ample materials for refuting such a theory, kept aloof from the strife; and whenever a zealous Neptunist wished to draw the old man into an argument, he was satisfied with replying, "Go and see."*

Hutton, 1788.—It would be contrary to all analogy, in matters of graver import, that a war should rage with such fury on the Continent, and that the inhabitants of our island should not mingle in the affray. Although in England the personal influence of Werner was wanting to stimulate men to the defence of the weaker side of the question, they contrived to find good reason for espousing the Wernerian errors with great enthusiasm. In order to explain the peculiar motives which led many to enter, even with party feeling, into this contest, it will be necessary to present the reader with a sketch of the views unfolded by Hutton, a contemporary of the Saxon geologist. The former naturalist had been educated as a physician, but, declining the practice of medicine, he resolved,

* Cuvier, Eloge de Desmarest.

when young, to remain content with the small independence inherited from his father, and thenceforth to give his undivided attention to scientific pursuits. He resided at Edinburgh, where he enjoyed the society of many men of high attainments, who loved him for the simplicity of his manners and the sincerity of his character. His application was unwearied; and he made frequent tours through different parts of England and Scotland, acquiring considerable skill as a mineralogist, and constantly arriving at grand and comprehensive views in geology. He communicated the results of his observations unreservedly, and with the fearless spirit of one who was conscious that love of truth was the sole stimulus of his exertions. When at length he had matured his views, he published, in 1788, his "Theory of the Earth *," and the same, afterwards more fully developed in a separate work, in 1795. This treatise was the first in which geology was declared to be in no way concerned about "questions as to the origin of things;" the first in which an attempt was made to dispense entirely with all hypothetical causes, and to explain the former changes of the earth's crust by reference exclusively to natural agents. Hutton laboured to give fixed principles to geology, as Newton had succeeded in doing to astronomy: but, in the former science, too little progress had been made towards furnishing the necessary data, to enable any philosopher, however great his genius, to realize so noble a project.

Huttonian theory.—"The ruins of an older world," said Hutton, "are visible in the present structure of our planet; and the strata which now compose our

* Ed. Phil. Trans. 1788.

continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted."

Although Hutton had never explored any region of active volcanos, he had convinced himself that basalt and many other trap-rocks were of igneous origin, and that many of them had been injected in a melted state through fissures in the older strata. The compactness of these rocks, and their different aspect from that of ordinary lava, he attributed to their having cooled down under the pressure of the sea; and in order to remove the objections started against this theory, his friend, Sir James Hall, instituted a most curious and instructive series of chemical experiments, illustrating the crystalline arrangement and texture assumed by melted matter cooled under high pressure.

The absence of stratification in granite, and its analogy in mineral character to rocks which he deemed of igneous origin, led Hutton to conclude that granite also must have been formed from matter in fusion; and this inference he felt could not be fully confirmed, unless he discovered at the contact of granite and other strata a repetition of the phenomena exhibited so constantly by the trap-rocks. Resolved to try his theory by this test, he went to the Grampians, and surveyed the line of junction of the granite and super-incumbent stratified masses, until he found in Glen Tilt,

in 1785, the most clear and unequivocal proofs in support of his views. Veins of red granite are there seen branching out from the principal mass, and traversing the black micaceous schist and primary limestone. The intersected stratified rocks are so distinct in colour and appearance as to render the example in that locality most striking, and the alteration of the limestone in contact was very analogous to that produced by trap veins on calcareous strata. This verification of his system filled him with delight, and called forth such marks of joy and exultation, that the guides who accompanied him, says his biographer, were convinced that he must have discovered a vein of silver or gold.* He was aware that the same theory would not explain the origin of the primary schists, but these he called primary, rejecting the term primitive, and was disposed to consider them as sedimentary rocks altered by heat, and that they originated in some other form from the waste of previously existing rocks.

By this important discovery of granite veins, to which he had been led by fair induction from an independent class of facts, Hutton prepared the way for the greatest innnovation on the systems of his predecessors. Vallisneri had pointed out the general fact that there were certain fundamental rocks which contained no organic remains, and which he supposed to have been formed before the creation of living beings. Moro, Generelli, and other Italian writers, embraced the same doctrine; and Lehman regarded the mountains called by him primitive, as parts of the original nucleus of the globe. The same tenet was an article

* Playfair's Works, vol. iv. p. 75.

of faith in the school of Freyberg; and if any one ventured to doubt the possibility of our being enabled to carry back our researches to the creation of the present order of things, the granitic rocks were triumphantly appealed to. On them seemed written, in legible characters, the memorable inscription—

> Dinanzi a me non fur cose create
> Se non eterne;

and no small sensation was excited when Hutton seemed, with unhallowed hand, desirous to erase characters already regarded by many as sacred. "In the economy of the world," said the Scotch geologist, "I can find no traces of a beginning, no prospect of an end;" a declaration the more startling when coupled with the doctrine, that all past changes on the globe had been brought about by the slow agency of existing causes. The imagination was first fatigued and overpowered by endeavouring to conceive the immensity of time required for the annihilation of whole continents by so insensible a process; and when the thoughts had wandered through these interminable periods, no resting place was assigned in the remotest distance. The oldest rocks were represented to be of a derivative nature, the last of an antecedent series, and that perhaps one of many pre-existing worlds. Such views of the immensity of past time, like those unfolded by the Newtonian philosophy in regard to space, were too vast to awaken ideas of sublimity unmixed with a painful sense of our incapacity to conceive a plan of such infinite extent. Worlds are seen beyond worlds immeasurably distant from each other, and, beyond them all, innumerable other systems are faintly traced on the confines of the visible universe.

The characteristic feature of the Huttonian theory was, as before hinted, the exclusion of all causes not supposed to belong to the present order of nature. But Hutton had made no step beyond Hooke, Moro, and Raspe, in pointing out in what manner the laws now governing subterranean movements might bring about geological changes, if sufficient time be allowed. On the contrary, he seems to have fallen far short of some of their views, especially when he refused to attribute any part of the external configuration of the earth's crust to subsidence. He imagined that the continents were first gradually destroyed by aqueous degradation; and when their ruins had furnished materials for new continents, they were upheaved by violent convulsions. He therefore required alternate periods of general disturbance and repose; and such he believed had been, and would for ever be, the course of nature.

Generelli, in his exposition of Moro's system, had made a far nearer approximation towards reconciling geological appearances with the state of nature as known to us; for while he agreed with Hutton, that the decay and reproduction of rocks were always in progress, proceeding with the utmost uniformity, the learned Carmelite represented the repairs of mountains by elevation from below to be effected by an equally constant and synchronous operation. Neither of these theories, considered singly, satisfies all the conditions of the great problem, which a geologist, who rejects cosmological causes, is called upon to solve; but they probably contain together the germs of a perfect system. There can be no doubt, that periods of disturbance and repose have followed each other in succession in every region of the globe; but it

may be equally true, that the energy of the subterranean movements has been always uniform as regards the *whole earth*. The force of earthquakes may for a cycle of years have been invariably confined, as it is now, to large but determinate spaces, and may then have gradually shifted its position, so that another region, which had for ages been at rest, became in its turn the grand theatre of action.

Playfair's illustrations of Hutton.—The explanation proposed by Hutton and by Playfair, the illustrator of his theory, respecting the origin of valleys, and of alluvial accumulations, was also very imperfect. They ascribed none of the inequalities of the earth's surface to movements which accompanied the upheaving of the land, imagining that valleys in general were formed in the course of ages, by the rivers now flowing in them; while they seem not to have reflected on the excavating and transporting power which the waves of the ocean might exert on land during its emergence.

Although Hutton's knowledge of mineralogy and chemistry was considerable, he possessed but little information concerning organic remains; they merely served him, as they did Werner, to characterize certain strata, and to prove their marine origin. The theory of former revolutions in organic life was not yet fully recognized; and without this class of proofs in support of the antiquity of the globe, the indefinite periods demanded by the Huttonian hypothesis appeared visionary to many; and some, who deemed the doctrine inconsistent with revealed truths, indulged very uncharitable suspicions of the motives of its author. They accused him of a deliberate design of reviving the heathen dogma of an "eternal succession," and of denying that this world ever had a beginning. Playfair,

in the biography of his friend, has the following comment on this part of their theory: — "In the planetary motions, where geometry has carried the eye so far, both into the future and the past, we discover no mark either of the commencement or termination of the present order. It is unreasonable, indeed, to suppose that such marks should any where exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in His works any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. *He may put an end, as he no doubt gave a beginning*, to the present system, at some determinate period of time; but we may rest assured that this great catastrophe will not be brought about by the laws now existing, and that it is not indicated by any thing which we perceive." *

The party feeling excited against the Huttonian doctrines, and the open disregard of candour and temper in the controversy, will hardly be credited by the reader, unless he recalls to his recollection that the mind of the English public was at that time in a state of feverish excitement. A class of writers in France had been labouring industriously, for many years, to diminish the influence of the clergy, by sapping the foundations of the Christian faith; and their success, and the consequences of the Revolution, had alarmed the most resolute minds, while the imagination of the more timid was continually haunted by dread of innovation, as by the phantom of some fearful dream.

* Playfair's Works, vol. iv. p. 55.

Voltaire.—Voltaire had used the modern discoveries in physics as one of the numerous weapons of attack and ridicule directed by him against the Scriptures. He found that the most popular systems of geology were accommodated to the sacred writings, and that much ingenuity had been employed to make every fact coincide exactly with the Mosaic account of the creation and deluge. It was, therefore, with no friendly feelings that he contemplated the cultivators of geology in general, regarding the science as one which had been successfully enlisted by theologians as an ally in their cause.* He knew that the majority of those who were aware of the abundance of fossil shells in the interior of continents, were still persuaded that they were proofs of the universal deluge; and as the readiest way of shaking this article of faith, he endeavoured to inculcate scepticism as to the real nature of such shells, and to recall from contempt the exploded dogma of the sixteenth century, that they were sports of nature. He also pretended that vegetable impressions were not those of real plants.† Yet he was perfectly convinced that the shells had really belonged to living testacea, as may be seen in his

* In allusion to the theories of Burnet, Woodward, and other physico-theological writers, he declared that they were as fond of changes of scene on the face of the globe, as were the populace at a play. "Every one of them destroys and renovates the earth after his own fashion, as Descartes framed it: for philosophers put themselves without ceremony in the place of God, and think to create a universe with a word."—Dissertation envoyée à l'Académie de Boulogne, sur les Changemens arrivés dans notre Globe. Unfortunately, this and similar ridicule directed against the cosmogonists was too well deserved.

† See the chapter on "Des Pierres figurés."

essay "On the Formation of Mountains." * He would sometimes, in defiance of all consistency, shift his ground when addressing the vulgar; and, admitting the true nature of the shells collected in the Alps and other places, pretend that they were Eastern species, which had fallen from the hats of pilgrims coming from Syria. The numerous essays written by him on geological subjects were all calculated to strengthen prejudices, partly because he was ignorant of the real state of the science, and partly from his bad faith.† On the other hand, they who knew that his attacks were directed by a desire to invalidate Scripture, and who were unacquainted with the true merits of the question, might well deem the old diluvian hypothesis incontrovertible, if Voltaire could adduce no better argument against it than to deny the true nature of organic remains.

It is only by careful attention to impediments originating in extrinsic causes, that we can explain the slow and reluctant adoption of the simplest truths in geology. First, we find many able naturalists adducing the fossil remains of marine animals as proofs of an event related in Scripture. The evidence is deemed

* In that essay he lays it down, "that all naturalists are now agreed that deposits of shells in the midst of the continents are monuments of the continued occupation of these districts by the ocean." In another place also, when speaking of the fossil shells of Touraine, he admits their true origin.

† As an instance of his desire to throw doubt indiscriminately on all geological data, we may recall the passage where he says, that "the bones of a rein-deer and hippopotamus discovered near Etampes did not prove, as some would have it, that Lapland and the Nile were once on a tour from Paris to Orleans, but merely that a lover of curiosities once preserved them in his cabinet."

conclusive by the multitude for a century or more; for it favours opinions which they entertained before, and they are gratified by supposing them confirmed by fresh and unexpected proofs. Many, who see through the fallacy, have no wish to undeceive those who are influenced by it, approving the effect of the delusion, and conniving at it as a pious fraud; until, finally, an opposite party, who are hostile to the sacred writings, labour to explode the erroneous opinion, by substituting for it another dogma which they know to be equally unsound.

The heretical Vulcanists were soon after openly assailed in England, by imputations of the most illiberal kind. We cannot estimate the malevolence of such a persecution, by the pain which similar insinuations might now inflict: for although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement; and it was better, perhaps, for a man's good reception in society, that his moral character should have been traduced, than that he should become a mark for these poisoned weapons.

I shall pass over the works of numerous divines, who may be excused for sensitiveness on points which then excited so much uneasiness in the public mind; and shall say nothing of the amiable poet Cowper*, who could hardly be expected to have inquired into the merit of doctrines in physics. But in the foremost ranks of the intolerant, are found several laymen who had high claims to scientific reputation. Among these appears Williams, a mineral surveyor of Edinburgh, who published a "Natural History of the Mineral

* The Task, book iii. "The Garden."

Kingdom," in 1789; a work of great merit for that day, and of practical utility, as containing the best account of the coal strata. In his preface he misrepresents Hutton's theory altogether, and charges him with considering all rocks to be lavas of different colours and structure; and also with "warping every thing to support the eternity of the world."* He descants on the pernicious influence of such sceptical notions, as leading to downright infidelity and atheism, "and as being nothing less than to depose the Almighty Creator of the universe from his office."†

Kirwan.—De Luc.—Kirwan, president of the Royal Academy of Dublin, a chemist and mineralogist of some merit, but who possessed much greater authority in the scientific world than he was entitled by his talents to enjoy, said, in the introduction to his "Geological Essays, 1799," "that *sound* geology *graduated* into religion, and was required to dispel certain systems of atheism or infidelity, of which they had had recent experience."‡ He was an uncompromising defender of the aqueous theory of all rocks, and was scarcely surpassed by Burnet and Whiston, in his desire to adduce the Mosaic writings in confirmation of his opinions.

De Luc, in the preliminary discourse to his Treatise on Geology§, says, "the weapons have been changed by which revealed religion is attacked; it is now assailed by geology, and the knowledge of this science has become essential to theologians." He imputes the failure of former geological systems to their having been anti-mosaical, and directed against a "sublime tradition." These and similar imputations, reiterated

* P. 577. † P. 59.

‡ Introd. p. 2. § London, 1809.

in the works of De Luc, seem to have been taken for granted by some modern writers: it is therefore necessary to state, in justice to the numerous geologists of different nations, whose works have been considered, that none of them were guilty of endeavouring, by arguments drawn from physics, to invalidate scriptural tenets. On the contrary, the majority of them who were fortunate enough "to discover the true causes of things," rarely deserved another part of the poet's panegyric, "*Atque metus omnes subjecit pedibus.*" The caution, and even timid reserve, of many eminent Italian authors of the earlier period is very apparent: and there can hardly be a doubt, that they subscribed to certain dogmas, and particularly to the first diluvian theory, out of deference to popular prejudices, rather than from conviction. If they were guilty of dissimulation, we may feel regret, but must not blame their want of moral courage, reserving rather our condemnation for the intolerance of the times, and that inquisitorial power which forced Galileo to abjure, and the two Jesuits to disclaim the theory of Newton.*

* In a most able article, by Mr. Drinkwater, on the "Life of Galileo," published in the "Library of Useful Knowledge," it is stated that both Galileo's work, and the book of Copernicus "Nisi corrigatur" (for, with the omission of certain passages, it was sanctioned), were still to be seen on the forbidden list of the Index at Rome in 1828. I was however assured in the same year, by Professor Scarpellini, at Rome, that Pius VII., a pontiff distinguished for his love of science, had procured a repeal of the edicts against Galileo and the Copernican system. He had assembled the Congregation; and the late Cardinal Toriozzi, assessor of the Sacred Office, proposed "that they should wipe off this scandal from the church." The repeál was carried, with the dissentient voice of one Dominican only. Long before that time the Newtonian

Hutton answered Kirwan's attacks with great warmth, and with the indignation justly excited by unmerited reproach. "He had always displayed," says Playfair, "the utmost disposition to admire the beneficent design manifested in the structure of the world; and he contemplated with delight those parts of his theory which made the greatest additions to our knowledge of final causes." We may say with equal truth, that in no scientific works in our language can more eloquent passages be found, concerning the fitness, harmony, and grandeur of all parts of the creation, than in those of Playfair. They are evidently the unaffected expressions of a mind, which contemplated the study of nature, as best calculated to elevate our conceptions of the attributes of the First Cause. At any other time the force and elegance of Playfair's style must have insured popularity to the Huttonian doctrines; but, by a singular coincidence, Neptunianism and orthodoxy were now associated in the same creed; and the tide of prejudice ran so strong, that the majority were carried far away into the chaotic fluid, and other cosmological inventions of Werner. These fictions the Saxon professor had borrowed with little modification, and without any improvement, from his predecessors. They had not the smallest foundation either in Scripture or in common sense, and were probably approved of by many as being so ideal and unsubstantial, that they could never come into violent collision with any preconceived opinions.

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theory had been taught in the Sapienza, and all Catholic universities in Europe (with the exception, I am told, of Salamanca); but it was always required of professors, in deference to the decrees of the church, to use the term *hypothesis*, instead of theory. They now speak of the Copernican *theory*.

According to De Luc, the first essential distinction to be made between the various phenomena exhibited on the surface of the earth was, to determine which were the results of causes still in action, and which had been produced by causes that had ceased to act. The form and composition of the mass of our continents, he said, and their existence above the level of the sea, must be ascribed to causes no longer in action. These continents emerged at no very remote period on the sudden retreat of the ocean, the waters of which made their way into subterranean caverns. The formation of the rocks which enter into the crust of the earth began with the precipitation of granite from a primordial liquid, after which other strata containing the remains of organized bodies were deposited, till at last the present sea remained as the residuum of the primordial liquid, and no longer continued to produce mineral strata.*

William Smith, 1790.—While the tenets of the rival schools of Freyberg and Edinburgh were warmly espoused by devoted partisans, the labours of an individual, unassisted by the advantages of wealth or station in society, were almost unheeded. Mr. William Smith, an English surveyor, published his "Tabular View of the British Strata" in 1790, wherein he proposed a classification of the secondary formations in the West of England. Although he had not communicated with Werner, it appeared by this work that he had arrived at the same views respecting the laws of superposition of stratified rocks; that he was aware that the order of succession of different groups was never inverted;

* Elementary Treatise on Geology. London, 1809. Translated by De la Fite.

and that they might be identified at very distant points by their peculiar organized fossils.

From the time of the appearance of the "Tabular View," the author laboured to construct a geological map of the whole of England; and with the greatest disinterestedness of mind, communicated the results of his investigations to all who desired information, giving such publicity to his original views, as to enable his contemporaries almost to compete with him in the race. The execution of his map was completed in 1815, and remains a lasting monument of original talent and extraordinary perseverance; for he had explored the whole country on foot without the guidance of previous observers, or the aid of fellow-labourers, and had succeeded in throwing into natural divisions the whole complicated series of British rocks. D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise to this remarkable performance, observing, that "what many celebrated mineralogists had only accomplished for a small part of Germany in the course of half a century, had been effected by a single individual for the whole of England.*

Werner invented a new language to express his divisions of rocks, and some of his technical terms, such as grauwacke, gneiss, and others, passed current in every country in Europe. Smith adopted for the most part English provincial terms, often of barbarous sound, such as gault, cornbrash, clunch clay; and affixed them to subdivisions of the British series. Many of these still retain their place in our scientific classifications, and attest his priority of arrangement.

* See Dr. Fitton's Memoir, before cited, p. 57.

MODERN PROGRESS OF GEOLOGY.

The contention of the rival factions of the Vulcanists and Neptunists had been carried to such a height, that these names had become terms of reproach ; and the two parties had been less occupied in searching for truth, than for such arguments as might strengthen their own cause, or serve to annoy their antagonists. A new school at last arose, who professed the strictest neutrality, and the utmost indifference to the systems of Werner and Hutton, and who resolved diligently to devote their labours to observation. The reaction, provoked by the intemperance of the conflicting parties, now produced a tendency to extreme caution. Speculative views were discountenanced, and, through fear of exposing themselves to the suspicion of a bias towards the dogmas of a party, some geologists became anxious to entertain no opinion whatever on the causes of phenomena, and were inclined to scepticism even where the conclusions deducible from observed facts scarcely admitted of reasonable doubt.

Geological Society of London.—But although the reluctance to theorize was carried somewhat to excess, no measure could be more salutary at such a moment than a suspension of all attempts to form what were termed "theories of the earth." A great body of new data were required ; and the Geological Society of London, founded in 1807, conduced greatly to the attainment of this desirable end. To multiply and record observations, and patiently to await the result at some future period, was the object proposed by them ; and it was their favourite maxim that the time was not yet come for a general system of geology, but that all must be content for many years to be exclusively en-

gaged in furnishing materials for future generalizations. By acting up to these principles with consistency, they in a few years disarmed all prejudice, and rescued the science from the imputation of being a dangerous, or at best but a visionary pursuit.

A distinguished modern writer has with truth remarked, that the advancement of three of the main divisions of geological inquiry have, during the last half century, been promoted successively by three different nations of Europe,—the Germans, the English, and the French.* We have seen that the systematic study of what may be called mineralogical geology had its origin, and chief point of activity in Germany, where Werner first described with precision the mineral characters of rocks. The classification of the secondary formations, each marked by their peculiar fossils, belongs, in a great measure, to England, where the labours before alluded to of Smith, and those of the most active members of the Geological Society of London, were steadily directed to these objects. The foundation of the third branch, that relating to the tertiary formations, was laid in France by the splendid work of Cuvier and Brongniart, published in 1808, "On the Mineral Geography and Organic Remains of the Neighbourhood of Paris."

We may still trace, in the language of the science and our present methods of arrangement, the various countries where the growth of these several departments of geology was at different times promoted. Many names of simple minerals and rocks remain to this day German; while the European divisions of the secondary strata are in great part English, and are, in-

* Whewell, British Critic, No. xvii. p. 187. 1831.

deed, often founded too exclusively on English types. Lastly, the subdivisions first established of the succession of strata in the Paris basin have served as normal groups, to which other tertiary deposits throughout Europe have been compared, even in cases where this standard, as will afterwards be shewn, was wholly inapplicable.*

No period could have been more fortunate for the discovery, in the immediate neighbourhood of Paris, of a rich store of well-preserved fossils, than the commencement of the present century; for at no former era had Natural History been cultivated with such enthusiasm in the French metropolis. The labours of Cuvier in comparative osteology, and of Lamarck in recent and fossil shells, had raised these departments of study to a rank of which they had never previously been deemed susceptible. Their investigations had eventually a powerful effect in dispelling the illusion which had long prevailed concerning the absence of analogy between the ancient and modern state of our planet. A close comparison of the recent and fossil species, and the inferences drawn in regard to their habits, accustomed the geologist to contemplate the earth as having been at successive periods the dwelling-place of animals and plants of different races, some terrestrial, and others aquatic — some fitted to live in seas, others in the waters of lakes and rivers. By the consideration of these topics, the mind was slowly and insensibly withdrawn from imaginary pictures of catastrophes and chaotic confusion, such as haunted the imagination of the early cosmogonists. Numerous proofs were discovered of the tranquil deposition of

* Book iv. chap. ii.

sedimentary matter, and the slow development of organic life. If many writers, and Cuvier himself in the number, still continued to maintain, that, "the thread of induction was broken*," yet, in reasoning by the strict rules of induction from recent to fossil species, they in a great measure disclaimed the dogma which in theory they professed. The adoption of the same generic, and in some cases, even of the same specific, names for the exuviæ of fossil animals and their living analogues, was an important step towards familiarizing the mind with the idea of the identity and unity of the system in distant eras. It was an acknowledgment, as it were, that part at least of the ancient memorials of nature were written in a living language. The growing importance, then, of the natural history of organic remains may be pointed out as the characteristic feature of the progress of the science during the present century. This branch of knowledge has already become an instrument of great utility in geological classification, and is continuing daily to unfold new data for grand and enlarged views respecting the former changes of the earth.

When we compare the result of observations in the last thirty years with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the

* Discours sur les Révol. &c.

astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never-ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy: to trace the same system through various transformations—to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer were measured the regions of space, and the relative distances of the heavenly bodies—by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events—a succession of phenomena in the animate and inanimate worlds—signs which convey to our minds more definite ideas than figures can do of the immensity of time.

Whether our investigation of the earth's history and structure will eventually be productive of as great practical benefits to mankind, as a knowledge of the distant heavens, must remain for the decision of posterity. It was not till astronomy had been enriched by the observations of many centuries, and had made its way against popular prejudices to the establishment of a sound theory, that its application to the useful arts was most conspicuous. The cultivation of geology began at a later period; and in every step which it has hitherto made towards sound theoretical principles, it has had to contend against more violent prepossessions. The practical advantages already derived from it have not been inconsiderable: but our generalizations are

yet imperfect, and they who come after us may be expected to reap the most valuable fruits of our labour. Meanwhile the charm of first discovery is our own; and, as we explore this magnificent field of inquiry, the sentiment of a great historian of our times may continually be present to our minds, that "he who calls what has vanished back again into being, enjoys a bliss like that of creating."*

* Niebuhr's Hist. of Rome, vol. i. p. 5. Hare and Thirlwall's translation.

CHAPTER V.

CAUSES WHICH HAVE RETARDED THE PROGRESS OF GEOLOGY.

Effects of prepossessions in regard to the duration of past time— Of prejudices arising from our peculiar position as inhabitants of the land (p. 118.)—Of those occasioned by our not seeing subterranean changes now in progress — All these causes combine to make the former course of Nature appear different from the present.—Several objections to the assumption, that existing causes have produced the former changes of the earth's surface, removed by modern discoveries (p. 122.).

If we reflect on the history of the progress of geology, as explained in the preceding chapters, we perceive that there have been great fluctuations of opinion respecting the nature of the causes to which all former changes of the earth's surface are referrible. The first observers conceived the monuments which the geologist endeavours to decipher to relate to an original state of the earth, or to a period when there were causes in activity, distinct, in kind and degree, from those now constituting the economy of nature. These views were gradually modified, and some of them entirely abandoned in proportion as observations were multiplied, and the signs of former mutations more skilfully interpreted. Many appearances, which had for a long time been regarded as indicating mysterious and extraordinary agency, were finally recognized as the necessary result of the laws now governing

the material world; and the discovery of this unlooked-for conformity has at length induced some philosophers to infer, that, during the ages contemplated in geology, there has never been any interruption to the agency of the same uniform laws of change. The same assemblage of general causes, they conceive, may have been sufficient to produce, by their various combinations, the endless diversity of effects, of which the shell of the earth has preserved the memorials; and, consistently with these principles, the recurrence of analogous changes is expected by them in time to come.

Whether we coincide or not in this doctrine, we must admit that the gradual progress of opinion concerning the succession of phenomena in very remote eras, resembles, in a singular manner, that which has accompanied the growing intelligence of every people, in regard to the economy of nature in their own times. In an early stage of advancement, when a great number of natural appearances are unintelligible, an eclipse, an earthquake, a flood, or the approach of a comet, with many other occurrences afterwards found to belong to the regular course of events, are regarded as prodigies. The same delusion prevails as to moral phenomena, and many of these are ascribed to the intervention of demons, ghosts, witches, and other immaterial and supernatural agents. By degrees, many of the enigmas of the moral and physical world are explained, and, instead of being due to extrinsic and irregular causes, they are found to depend on fixed and invariable laws. The philosopher at last becomes convinced of the undeviating uniformity of secondary causes; and, guided by his faith in this principle, he determines the probability of accounts transmitted to

him of former occurrences, and often rejects the fabulous tales of former times, on the ground of their being irreconcilable with the experience of more enlightened ages.

Prepossessions in regard to the duration of past time.— As a belief in the want of conformity in the causes by which the earth's crust has been modified in ancient and modern periods was, for a long time, universally prevalent, and that, too, amongst men who have been convinced that the order of nature is *now* uniform, and that it has continued so for several thousand years, every circumstance which could have influenced their minds and given an undue bias to their opinions deserves particular attention. Now the reader may easily satisfy himself, that, however undeviating the course of nature may have been from the earliest epochs, it was impossible for the first cultivators of geology to come to such a conclusion, so long as they were under a delusion as to the age of the world, and the date of the first creation of animate beings. However fantastical some theories of the sixteenth century may now appear to us, — however unworthy of men of great talent and sound judgment, — we may rest assured that, if the same misconception now prevailed in regard to the memorials of human transactions, it would give rise to a similar train of absurdities. Let us imagine, for example, that Champollion, and the French and Tuscan literati lately engaged in exploring the antiquities of Egypt, had visited that country with a firm belief that the banks of the Nile were never peopled by the human race before the beginning of the nineteenth century, and that their faith in this dogma was as difficult to shake as the opinion of our ancestors, that the earth was never the abode of living

beings until the creation of the present continents, and of the species now existing,—it is easy to perceive what extravagant systems they would frame, while under the influence of this delusion, to account for the monuments discovered in Egypt. The sight of the pyramids, obelisks, colossal statues, and ruined temples, would fill them with such astonishment, that for a time they would be as men spell-bound—wholly incapable of reasoning with sobriety. They might incline at first to refer the construction of such stupendous works to some superhuman powers of a primeval world. A system might be invented resembling that so gravely advanced by Manetho, who relates that a dynasty of gods originally ruled in Egypt, of whom Vulcan, the first monarch, reigned nine thousand years; after whom came Hercules and other demigods, who were at last succeeded by human kings.

When some fanciful speculations of this kind had amused their imaginations for a time, some vast repository of mummies would be discovered, and would immediately undeceive those antiquaries who enjoyed an opportunity of personally examining them; but the prejudices of others at a distance, who were not eye-witnesses of the whole phenomena, would not be so easily overcome. The concurrent report of many travellers would, indeed, render it necessary for them to accommodate ancient theories to some of the new facts, and much wit and ingenuity would be required to modify and defend their old positions. Each new invention would violate a greater number of known analogies; for if a theory be required to embrace some false principle, it becomes more visionary in proportion as facts are multiplied, as would be the case if geometers were now required to form an astronomical

system on the assumption of the immobility of the earth.

Amongst other fanciful conjectures concerning the history of Egypt, we may suppose some of the following to be started. "As the banks of the Nile have been so recently colonized for the first time, the curious substances called mummies could never in reality have belonged to men. They may have been generated by some *plastic virtue* residing in the interior of the earth, or they may be abortions of nature produced by her incipient efforts in the work of creation. For if deformed beings are sometimes born even now, when the scheme of the universe is fully developed, many more may have been 'sent before their time, scarce half made up,' when the planet itself was in the embryo state. But if these notions appear to derogate from the perfection of the Divine attributes, and if these mummies be in all their parts true representations of the human form, may we not refer them to the future rather than the past? May we not be looking into the womb of Nature, and not her grave? May not these images be like the shades of the unborn in Virgil's Elysium—the archetypes of men not yet called into existence?"

These speculations, if advocated by eloquent writers, would not fail to attract many zealous votaries, for they would relieve men from the painful necessity of renouncing preconceived opinions. Incredible as such scepticism may appear, it has been rivalled by many systems of the sixteenth and seventeenth centuries, and among others by that of the learned Falloppio, who regarded the tusks of fossil elephants as earthy concretions, and the pottery or fragments of vases in the Monte Testaceo, near Rome, as works of nature, and

not of art. But when one generation had passed away, and another, not compromised to the support of antiquated dogmas had succeeded, they would review the evidence afforded by mummies more impartially, and would no longer controvert the preliminary question, that human beings had lived in Egypt before the nineteenth century: so that when a hundred years perhaps had been lost, the industry and talents of the philosopher would be at last directed to the elucidation of points of real historical importance.

But the above arguments are aimed against one only of many prejudices with which the earlier geologists had to contend. Even when they conceded that the earth had been peopled with animate beings at an earlier period than was at first supposed, they had no conception that the quantity of time bore so great a proportion to the historical era as is now generally conceded. How fatal every error as to the quantity of time must prove to the introduction of rational views concerning the state of things in former ages, may be conceived by supposing the annals of the civil and military transactions of a great nation to be perused under the impression that they occurred in a period of one hundred instead of two thousand years. Such a portion of history would immediately assume the air of a romance; the events would seem devoid of credibility, and inconsistent with the present course of human affairs. A crowd of incidents would follow each other in thick succession. Armies and fleets would appear to be assembled only to be destroyed, and cities built merely to fall in ruins. There would be the most violent transitions from foreign or intestine war to periods of profound peace, and the works effected during the years of disorder or

tranquillity would appear alike superhuman in magnitude.

He who should study the monuments of the natural world under the influence of a similar infatuation, must draw a no less exaggerated picture of the energy and violence of causes, and must experience the same insurmountable difficulty in reconciling the former and present state of nature. If we could behold in one view all the volcanic cones thrown up in Iceland, Italy, Sicily, and other parts of Europe, during the last five thousand years, and could see the lavas which have flowed during the same period; the dislocations, subsidences, and elevations caused by earthquakes; the lands added to various deltas, or devoured by the sea, together with the effects of devastation by floods, and imagine that all these events had happened in one year, we must form most exalted ideas of the activity of the agents, and the suddenness of the revolutions. Were an equal amount of change to pass before our eyes in the next year, could we avoid the conclusion that some great crisis of nature was at hand? If geologists, therefore, have misinterpreted the signs of a succession of events, so as to conclude that centuries were implied where the characters imported thousands of years, and thousands of years where the language of nature signified millions, they could not, if they reasoned logically from such false premises, come to any other conclusion than that the system of the natural world had undergone a complete revolution.

We should be warranted in ascribing the erection of the great pyramid to superhuman power, if we were convinced that it was raised in one day; and if we imagine, in the same manner, a mountain-chain to have been elevated, during an equally small fraction

of the time which was really occupied in upheaving it, we might then be justified in inferring, that the subterranean movements were once far more energetic than in our own times. We know that one earthquake may raise the coast of Chili for a hundred miles to the average height of about five feet. A repetition of two thousand shocks, of equal violence, might produce a mountain-chain one hundred miles long, and ten thousand feet high. Now, should one only of these convulsions happen in a century, it would be consistent with the order of events experienced by the Chilians from the earliest times; but if the whole of them were to occur in the next hundred years, the entire district must be depopulated, scarcely any animals or plants could survive, and the surface would be one confused heap of ruin and desolation.

One consequence of undervaluing greatly the quantity of past time, is the apparent coincidence which it occasions of events necessarily disconnected, or which are so unusual, that it would be inconsistent with all calculation of chances to suppose them to happen at one and the same time. When the unlooked-for association of such rare phenomena is witnessed in the present course of nature, it scarcely ever fails to excite a suspicion of the preternatural in those minds which are not firmly convinced of the uniform agency of secondary causes;—as if the death of some individual in whose fate they are interested happens to be accompanied by the appearance of a luminous meteor, or a comet, or the shock of an earthquake. It would be only necessary to multiply such coincidences indefinitely, and the mind of every philosopher would be disturbed. Now it would be difficult to exaggerate the number of physical events, many of them most

rare and unconnected in their nature, which were imagined by the Woodwardian hypothesis to have happened in the course of a few months: and numerous other examples might be found of popular geological theories, which require us to imagine that a long succession of events happened in a brief and almost momentary period.

Another liability to error, very nearly allied to the former, arises from the frequent contact of geological monuments referring to very distant periods of time. We often behold, at one glance, the effects of causes which have happened at times incalculably remote, and yet there may be no striking circumstances to mark the occurrence of a great chasm in the chronological series of Nature's archives. In the vast interval of time which may really have elapsed between the results of operations thus compared, the physical condition of the earth may, by slow and insensible modifications, have become entirely altered; one or more races of organic beings may have passed away, and yet have left behind, in the particular region under contemplation, no trace of their existence.

To a mind unconscious of these intermediate events, the passage from one state of things to another must appear so violent, that the idea of revolutions in the system inevitably suggests itself. The imagination is as much perplexed by the deception, as it might be if two distant points in space were suddenly brought into immediate proximity. Let us suppose, for a moment, that a philosopher should lie down to sleep in some arctic wilderness, and then be transferred by a power, such as we read of in tales of enchantment, to a valley in a tropical country, where, on awaking, he might find himself surrounded by birds of brilliant plumage,

and all the luxuriance of animal and vegetable forms of which Nature is so prodigal in those regions. The most reasonable supposition, perhaps, which he could make, if by the necromancer's art he was placed in such a situation, would be, that he was dreaming; and if a geologist form theories under a similar delusion, we cannot expect him to preserve more consistency in his speculations, than in the train of ideas in an ordinary dream.

The sources of prejudice hitherto considered may be deemed peculiar for the most part to the infancy of the science, but others are common to the first cultivators of geology and to ourselves, and are all singularly calculated to produce the same deception, and to strengthen our belief that the course of nature in the earlier ages differed widely from that now established. Although these circumstances cannot be fully explained without assuming some things as proved, which it will be the object of another part of this work to demonstrate, it may be well to allude to them briefly in this place.

Prejudices arising from our peculiar position as inhabitants of the land. — The first and greatest difficulty, then, consists in an habitual unconsciousness that our position as observers is essentially unfavourable, when we endeavour to estimate the magnitude of the changes now in progress. In consequence of our inattention to this subject, we are liable to serious mistakes in contrasting the present with former states of the globe. As dwellers on the land, we inhabit about a fourth part of the surface; and that portion is almost exclusively a theatre of decay, and not of reproduction. We know, indeed, that new deposits are annually formed in seas and lakes, and that every year some

new igneous rocks are produced in the bowels of the earth, but we cannot watch the progress of their formation; and as they are only present to our minds by the aid of reflection, it requires an effort both of the reason and the imagination to appreciate duly their importance. It is, therefore, not surprising that we estimate very imperfectly the result of operations thus invisible to us; and that, when analogous results of former epochs are presented to our inspection, we cannot immediately recognize the analogy. He who has observed the quarrying of stone from a rock, and has seen it shipped for some distant port, and then endeavours to conceive what kind of edifice will be raised by the materials, is in the same predicament as a geologist, who, while he is confined to the land, sees the decomposition of rocks, and the transportation of matter by rivers to the sea, and then endeavours to picture to himself the new strata which Nature is building beneath the waters.

Prejudices arising from our not seeing subterranean changes. — Nor is his position less unfavourable when, beholding a volcanic eruption, he tries to conceive what changes the column of lava has produced, in its passage upwards, on the intersected strata; or what form the melted matter may assume at great depths on cooling; or what may be the extent of the subterranean rivers and reservoirs of liquid matter far beneath the surface. It should, therefore, be remembered, that the task imposed on those who study the earth's history requires no ordinary share of discretion; for we are precluded from collating the corresponding parts of the system of things as it exists now, and as it existed at former periods. If we were inhabitants of another element — if the great ocean were our

domain, instead of the narrow limits of the land, our difficulties would be considerably lessened; while, on the other hand, there can be little doubt, although the reader may, perhaps, smile at the bare suggestion of such an idea, that an amphibious being, who should possess our faculties, would still more easily arrive at sound theoretical opinions in geology, since he might behold, on the one hand, the decomposition of rocks in the atmosphere, or the transportation of matter by running water; and, on the other, examine the deposition of sediment in the sea, and the imbedding of animal and vegetable remains in new strata. He might ascertain, by direct observation, the action of a mountain torrent, as well as of a marine current; might compare the products of volcanos poured out upon the land with those ejected beneath the waters; and might mark, on the one hand, the growth of the forest, and on the other that of the coral reef. Yet, even with these advantages, he would be liable to fall into the greatest errors when endeavouring to reason on rocks of subterranean origin. He would seek in vain, within the sphere of his observation, for any direct analogy to the process of their formation, and would therefore be in danger of attributing them, wherever they are upraised to view, to some "primeval state of nature."

But if we may be allowed so far to indulge the imagination, as to suppose a being entirely confined to the nether world — some "dusky melancholy sprite," like Umbriel, who could "flit on sooty pinions to the central earth," but who was never permitted to "sully the fair face of light," and emerge into the regions of water and of air; and if this being should busy himself in investigating the structure of the globe, he might

frame theories the exact converse of those usually adopted by human philosophers. He might infer that the stratified rocks, containing shells and other organic remains, were the oldest of created things, belonging to some original and nascent state of the planet. "Of these masses," he might say, "whether they consist of loose incoherent sand, soft clay, or solid stone, none have been formed in modern times. Every year some part of them are broken and shattered by earthquakes, or melted by volcanic fire; and, when they cool down slowly from a state of fusion, they assume a new and more crystalline form, no longer exhibiting that stratified disposition, and those curious impressions and fantastic markings, by which they were previously characterized. This process cannot have been carried on for an indefinite time, for in that case all the stratified rocks would long ere this have been fused and crystallized. It is therefore probable that the whole planet once consisted of these mysterious and curiously bedded formations at a time when the volcanic fire had not yet been brought into activity. Since that period there seems to have been a gradual development of heat; and this augmentation we may expect to continue till the whole globe shall be in a state of fluidity and incandescence."

Such might be the system of the Gnome at the very time that the followers of Leibnitz, reasoning on what they saw on the outer surface, might be teaching the opposite doctrine of gradual refrigeration, and averring that the earth had begun its career as a fiery comet, and might be destined hereafter to become a frozen mass. The tenets of the schools of the nether and of the upper world would be directly opposed to each other, for both would partake of the prejudices in-

evitably resulting from the continual contemplation of one class of phenomena to the exclusion of another. Man observes the annual decomposition of crystalline and igneous rocks, and may sometimes see their conversion into stratified deposits; but he cannot witness the reconversion of the sedimentary into the crystalline by subterranean fire. He is in the habit of regarding all the sedimentary rocks as more recent than the unstratified, for the same reason that we may suppose him to fall into the opposite error if he saw the origin of the igneous class only.

ASSUMPTION OF THE DISCORDANCE OF THE ANCIENT AND EXISTING CAUSES OF CHANGE UNPHILOSOPHICAL.

It is only by becoming sensible of our natural disadvantages that we shall be roused to exertion, and prompted to seek out opportunities of observing such of the operations now in progress, as do not present themselves readily to view. We are called upon, in our researches into the state of the earth, as in our endeavours to comprehend the mechanism of the heavens, to invent means for overcoming the limited range of our vision. We are perpetually required to bring, as far as possible, within the sphere of observation, things to which the eye, unassisted by art, could never obtain access.

It was not an impossible contingency, that astronomers might have been placed at some period in a situation much resembling that in which the geologist seems to stand at present. If the Italians, for example, in the early part of the twelfth century, had discovered at Amalfi, instead of the pandects of Justinian, some

ancient manuscripts filled with astronomical observations relating to a period of three thousand years, and made by some ancient geometers who possessed optical instruments as perfect as any in modern Europe, they would probably, on consulting these memorials, have come to a conclusion that there had been a great revolution in the solar and sidereal systems. "Many primary and secondary planets," they might say, "are enumerated in these tables, which exist no longer. Their positions are assigned with such precision, that we may assure ourselves that there is nothing in their place at present but the blue ether. Where one star is visible to us, these documents represent several thousands. Some of those which are now single, consisted then of two separate bodies, often distinguished by different colours, and revolving periodically round a common centre of gravity. There is nothing analogous to them in the universe at present; for they were neither fixed stars nor planets, but seem to have stood in the mutual relation of sun and planet to each other. We must conclude, therefore, that there has occurred, at no distant period, a tremendous catastrophe, whereby thousands of worlds have been annihiliated at once, and some heavenly bodies absorbed into the substance of others." When such doctrines had prevailed for ages, the discovery of one of the worlds, supposed to have been lost, by aid of the first rude telescope invented after the revival of science, would not dissipate the delusion, for the whole burden of proof would now be thrown on those who insisted on the stability of the system from a remote period, and these philosophers would be required to demonstrate the existence of *all* the worlds said to have been annihilated.

Such popular prejudices would be most unfavourable to the advancement of astronomy; for, instead of persevering in the attempt to improve their instruments, and laboriously to make and record observations, the greater number would despair of verifying the continued existence of the heavenly bodies not visible to the naked eye. Instead of confessing the extent of their ignorance, and striving to remove it by bringing to light new facts, they would indulge in the more easy and indolent employment of framing imaginary theories concerning catastrophes and mighty revolutions in the system of the universe.

For more than two centuries the shelly strata of the Subapennine hills afforded matter of speculation to the early geologists of Italy, and few of them had any suspicion that similar deposits were then forming in the neighbouring sea. They were as unconscious of the continued action of causes still producing similar effects, as the astronomers, in the case above supposed, of the existence of certain heavenly bodies still giving and reflecting light, and performing their movements as of old. Some imagined that the strata, so rich in organic remains, instead of being due to secondary agents, had been so created in the beginning of things by the fiat of the Almighty; and others ascribed the imbedded fossil bodies to some plastic power which resided in the earth in the early ages of the world. At length Donati explored the bed of the Adriatic, and found the closest resemblance between the new deposits there forming, and those which constituted hills above a thousand feet high in various parts of the Italian peninsula. He ascertained that certain genera of living testacea were grouped together at the bottom of the sea, in precisely the same manner as were

their fossil analogues in the strata of the hills, and that some species were common to the recent and fossil world. Beds of shells, moreover, in the Adriatic, were becoming incrusted with calcareous rock: and others were recently inclosed in deposits of sand and clay, precisely as fossil shells were found in the hills. This splendid discovery of the identity of modern and ancient submarine operations was not made without the aid of artificial instruments, which, like the telescope, brought phenomena into view not otherwise within the sphere of human observation.

In like manner, in the Vicentin, a great series of volcanic and marine sedimentary rocks was examined in the early part of the last century; but no geologists suspected, before the time of Arduino, that these were partly composed of ancient submarine lavas. If, when these inquiries were first made, geologists had been told that the mode of formation of such rocks might be fully elucidated by the study of processes then going on in certain parts of the Mediterranean, they would have been as incredulous as geometers would have been before the time of Newton, if any one had informed them that, by making experiments on the motion of bodies on the earth, they might discover the laws which regulated the movements of distant planets.

The establishment, from time to time, of numerous points of identification, drew at length from geologists a reluctant admission, that there was more correspondence between the physical constitution of the globe, and more uniformity in the laws regulating the changes of its surface, from the most remote eras to the present, than they at first imagined. If, in this state of the science, they still despaired of reconciling every class of geological phenomena to the operations of ordinary

causes, even by straining analogy to the utmost limits of credibility, we might have expected, at least, that the balance of probability would now have been presumed to incline towards the identity of the causes. But, after repeated experience of the failure of attempts to speculate on different classes of geological phenomena, as belonging to a distinct order of things, each new sect persevered systematically in the principles adopted by their predecessors. They invariably began, as each new problem presented itself, whether relating to the animate or inanimate world, to assume in their theories, that the economy of nature was formerly governed by rules for the most part independent of those now established. Whether they endeavoured to account for the origin of certain igneous rocks, or to explain the forces which elevated hills or excavated valleys, or the causes which led to the extinction of certain races of animals, they first presupposed an original and dissimilar order of nature; and when at length they approximated, or entirely came round to an opposite opinion, it was always with the feeling, that they conceded what they were justified *à priori* in deeming improbable. In a word, the same men who, as natural philosophers, would have been most incredulous respecting any extraordinary deviations from the known course of nature, if reported to have happened *in their own time*, were equally disposed, as geologists, to expect the proofs of such deviations at every period of the past.

I shall now proceed to enumerate some of the principal difficulties still opposed to the theory of the uniformity of the causes which have worked successive changes in the crust of the earth, and in the condition of its living inhabitants. The discussion of so im-

portant a question on the present occasion may appear premature, but it is one which naturally arises out of a review of the former history of the science. It is, of course, impossible to enter fully into such speculative topics, without occasionally carrying the novice beyond his depth, and appealing to facts and conclusions with which he must as yet be unacquainted; but his curiosity cannot fail to be excited by having his attention at once called to some of the principal points in controversy, and after reading the second, third, and fourth books, he may return again to these preliminary essays with increased interest and profit.

First, then, it is undeniable, that many objections to the doctrine of the uniform agency of geological causes have been partially or entirely removed by the progress of the science during the last forty years. It was objected, for example, to those who endeavoured to explain the formation of sedimentary strata by causes now in diurnal action, that they must take for granted incalculable periods of time. Now the time which they required has since become equally requisite to account for another class of phenomena brought to light by more recent investigations. It must always have been evident to unbiassed minds, that successive strata, containing, in regular order of superposition, distinct shells and corals, arranged in families as they grow at the bottom of the sea, could only have been formed by slow and insensible degrees in a great lapse of ages: yet, until organic remains were minutely examined and specifically determined, it was rarely possible to prove that the series of deposits met with in one country was not formed simultaneously with that found in another. But we are now able to determine, in numerous instances, the relative dates of

sedimentary rocks in distant regions, and to show, by their organic remains, that they were not of contemporary origin, but formed in succession. We often find, that where an interruption in the consecutive formations in one district is indicated by a sudden transition, from one assemblage of fossil species to another, the chasm is filled up, in some other district, by important groups of strata.*

The more attentively we study the European continent, the greater we find the extension of the whole series of geological formations. No sooner does the calendar appear to be completed, and the signs of a succession of physical events arranged in chronological order, than we are called upon to intercalate, as it were, some new period of vast duration. A geologist, whose observations have been confined to England, is accustomed to consider the superior and newer groups of marine strata in our island as modern,—and such they are, comparatively speaking; but when he has travelled through the Italian peninsula and Sicily, and has seen strata of more recent origin forming mountains several thousand feet high, and has marked a long series both of volcanic and submarine operations, all newer than any of the regular strata which enter largely into the physical structure of Great Britain, he returns with more exalted conceptions of the antiquity of some of our modern deposits than he before entertained of the oldest of the British series.

We cannot reflect on the concessions thus extorted from us, in regard to the duration of past time, without foreseeing that the period may arrive when part of the Huttonian theory will be combated on the ground of

* See Book iv. chap. iii.

its departing too far from the analogy of the present course of nature. On a closer investigation of extinct volcanos, we find proofs that they broke out at successive eras, and that the eruptions of one group were often concluded long before others had commenced their activity. Some were burning when one class of organic beings were in existence, others came into action when a different and new race of animals and plants existed:—it is more than probable, therefore, that the convulsions caused by subterranean movements, which seem to be merely another portion of the volcanic phenomena, have also occurred in succession; and their effects must be divided into separate sums, and assigned to separate periods of time. Nor is this all: when we examine the volcanic products, whether they be lavas which flowed out under water, or upon dry land, we find that intervals of time, often of great length, intervened between their formation, and that the effects of single eruptions were not greater in amount than those which now result from ordinary volcanic convulsions. The accompanying or preceding earthquakes, therefore, may be considered to have been also successive, often interrupted by long intervals of time, and not to have exceeded in violence those now experienced in the ordinary course of nature.

Already, therefore, may we regard the doctrine of the sudden elevation of whole continents by paroxysmal eruptions as invalidated; and there was the greatest inconsistency in the adoption of such a tenet by the Huttonians, who were anxious to reconcile former changes to the present economy of the world. It was contrary to analogy to suppose, that Nature had been at any former epoch parsimonious of time and prodigal of violence — to imagine that one district was not at

rest, while another was convulsed—that the disturbing forces were not kept under subjection, so as never to carry simultaneous havoc and desolation over the whole earth, or even over one great region. If it could have been shown, that a certain combination of circumstances would at some future period produce a crisis in the subterranean action, we should certainly have had no right to oppose our experience for the last three thousand years as an argument against the probability of such occurrences in past ages; but it is not pretended that such a combination can be foreseen.

In speculating on catastrophes by water, we may certainly anticipate great floods in future; and we may therefore presume that they have happened again and again in past times. The existence of enormous seas of fresh water, such as the North American lakes, the surface of the largest of which is elevated more than six hundred feet above the level of the ocean, and is in parts twelve hundred feet deep, is alone sufficient to assure us, that the time may come, however distant, when a deluge may lay waste a considerable part of the American continent. The depression, moreover, of part of Asia, bordering the Caspian Sea, to a depth of from one to three hundred feet below the level of the ocean, might easily give rise to a similar catastrophe.* No hypothetical agency is required to cause the sudden escape of the waters. Such changes of level, and opening of fissures, as have accompanied earthquakes since the commencement of the present century, or such excavation of ravines as the receding cataract of Niagara is now effecting, might breach the barriers. Notwithstanding, therefore, that we have

* See Book iv.

not witnessed within the last three thousand years the devastation by deluge of a large continent, yet, as we may predict the future occurrence of such catastrophes, we are authorized to regard them as part of the present order of Nature; and they may be introduced into geological speculations respecting the past, provided we do not imagine them to have been more frequent or general than we expect them to be in time to come.

The great contrast in the aspect of the older and newer rocks, in texture, structure, and the derangement of the strata, appeared formerly one of the strongest grounds for presuming that the causes to which they owed their origin were perfectly dissimilar from those now in operation. But this incongruity may be the result of subsequent modifications, since the difference of relative age is demonstrated to have been immense, so that, however slow and insensible the change, it must have become important in the course of so many ages. In addition to the influence of volcanic heat, we must allow for the effect of mechanical pressure, of chemical affinity, of percolation by mineral waters, of permeation by elastic fluids, and the action, perhaps, of many other forces less understood, such as electricity and magnetism. The extreme of alteration which may thus be effected, is probably exemplified in the highly crystalline, or granitiform, strata, to which the name of primary is usually given; but the theory of their origin must be postponed to the concluding chapters of the fourth Book.

In regard to the signs of the upraising, sinking, fracture, and contortion of rocks, it is evident that newer strata cannot be shaken by earthquakes, unless

the subjacent rocks are also affected; so that the contrast in the relative degree of disturbance in the more ancient and the newer strata, is one of many proofs that the convulsions have happened in different eras, and the fact confirms the uniformity of the action of subterranean forces, instead of their greater violence in the primeval ages.

Doctrine of Universal Formations. — The popular doctrine of universal formations, or the unlimited geographical extent of strata, distinguished by similar mineral characters, appeared for a long time to present insurmountable objections to the supposition, that the earth's crust had been formed by causes now acting. If it had merely been assumed, that rocks originating from fusion by subterranean fire presented in all parts of the globe a perfect correspondence in their mineral composition, the assumption would not have been extravagant; for, as the elementary substances that enter largely into the composition of rocks are few in number, they may be expected to arrange themselves invariably in the same forms, whenever the elementary particles are freely exposed to the action of chemical affinities. But when it was imagined that sedimentary mixtures, including animal and vegetable remains, and evidently formed in the beds of ancient lakes and seas, were of a homogeneous nature throughout a whole hemisphere, the dogma precluded at once all hope of recognizing the slightest analogy betwen the ancient and modern causes of decay and reproduction. We know that existing rivers carry down from different mountain chains sediment of distinct colours and composition: where the chains are near the sea, coarse sand and gravel is swept in; where they are distant, the finest mud.

We know, also, that the matter introduced by springs into lakes and seas is very diversified in mineral composition; in short, *contemporaneous* strata now in the progress of formation are greatly varied in their composition, and could never afford formations of homogeneous mineral ingredients co-extensive with the greater part of the earth's surface.

This theory, however, is in truth as inapplicable to the geological monuments found in the earth's crust, as to the effects of existing causes. The first investigators of sedimentary rocks had never reflected on the great areas occupied by the modern deltas of large rivers; still less on the much greater areas over which marine currents, preying alike on river-deltas, and continuous lines of sea-coast, diffuse homogeneous mixtures. They were ignorant of the vast spaces over which calcareous and other mineral springs abound upon the land and in the sea, especially in and near volcanic regions, and of the quantity of matter discharged by them. When, therefore, they ascertained the extent of the geographical distribution of certain groups of ancient strata—when they traced them continuously from one extremity of Europe to the other, and found them flanking, throughout their entire range, great mountain chains, they were astonished at so unexpected a discovery; and, considering themselves at liberty to disregard all modern analogy, they indulged in the sweeping generalization, that the law of continuity prevailed throughout strata of contemporaneous origin over the whole planet. The difficulty of dissipating this delusion was extreme, because some rocks, formed under similar circumstances at different epochs, present the same external characters, and often the same internal composition; and all these were assumed to

be contemporaneous until the contrary could be shown, which, in the absence of evidence derived from direct superposition, and in the scarcity of organic remains, was often impossible.

Innumerable other false generalizations have been derived from the same source; such, for instance, as the former universality of the ocean, now disproved by the discovery of the remains of terrestrial vegetation in strata of every age, even the most ancient. But I shall dwell no longer on exploded errors, but proceed at once to contend against weightier objections, which will require more attentive consideration.

CHAPTER VI.

FURTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Proofs that the climate of the Northern Hemisphere was formerly hotter — Direct proofs from the organic remains of the Sicilian and Italian strata — Proofs from analogy derived from extinct Quadrupeds — Imbedding of animals in Icebergs — Siberian Mammoths (p. 141.) — Evidence in regard to temperature, from the fossils of tertiary and secondary rocks (p. 153.) — From the Plants of the Coal formation — Northern limit of these fossils — Whether such plants could endure the long continuance of an arctic night (p. 155.).

Climate of the Northern Hemisphere formerly hotter. — That the climate of the Northern hemisphere has undergone an important change, and that its mean annual temperature must once have resembled that now experienced within the tropics, was the opinion of some of the first naturalists who investigated the contents of the ancient strata. Their conjecture became more probable when the shells and corals of the secondary rocks were more carefully examined; for these organic remains were found to be intimately connected by generic affinity with species now living in warmer latitudes. At a later period, many reptiles, such as turtles, tortoises, and large saurian animals, were discovered in European formations in great abundance; and they supplied new and powerful arguments, from analogy, in support of the doctrine, that the heat of

the climate had been great when our secondary strata were deposited. Lastly, when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation; for the flora of a country is peculiarly influenced by temperature: and the ancient vegetation of the earth might, more readily than the forms of animals, have afforded conflicting proofs, had the popular theory been without foundation. When the examination of animal and vegetable remains was extended to rocks in the most northern parts of Europe and North America, and even to the Arctic regions, indications of the same revolution in climate were discovered.

It cannot be said, that in this, as in many other departments of geology, we have investigated the phenomena of former eras, and neglected those of the present state of things. On the contrary, since the first agitation of this interesting question, the accessions to our knowledge of living animals and plants have been immense, and have far surpassed all the data previously obtained for generalizing, concerning the relation of certain types of organization to particular climates. The tropical and temperate zones of South America and of Australia have been explored; and, on close comparison, it has been found, that scarcely any of the species of the animate creation in these extensive continents are identical with those inhabiting the old world. Yet the zoologist and botanist, well acquainted with the geographical distribution of organic beings in other parts of the globe, would have been able, if distinct groups of species had been presented to them from these regions, to recognize those which had been collected from latitudes within, and those which were brought from without the tropics.

Before I attempt to explain the probable causes of great vicissitudes of temperature on the earth's surface, I shall take a rapid view of some of the principal data which appear to support the popular opinions now entertained on the subject. To insist on the soundness of these inferences, is the more necessary, because some zoologists have of late undertaken to vindicate the uniformity of the laws of nature, not by accounting for former fluctuations in climate, but by denying the value of the evidence in their favour.*

Direct proofs from the fossil remains of living species. — It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of Europe; there are direct proofs in confirmation of the same doctrine, in the only countries hitherto investigated by expert geologists where we could expect to meet with such proofs. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata where the organic remains belong to extinct species, but where living species abound in a fossil state, that a theory of climate can be subjected to the experimentum crucis. In Sicily, Ischia, and Calabria, where the fossil testacea of the more recent strata belong almost entirely to species now inhabiting the Mediterranean, the conchologist remarks, that individuals in the inland deposits often exceed in their average size their living analogues, as if the circum-

* See two articles by the Rev. Dr. Fleming, in the Edinburgh New Phil. Journ. No. xii. p. 277., April, 1829; and No. xv. p. 65., Jan. 1830.

stances under which they formerly lived were more favourable to their development. Yet no doubt can be entertained of their specific identity on the ground of such difference in their dimensions; because living individuals of many of these species still attain, in warmer latitudes, the average size of the fossils.

I collected several hundred species of shells in Sicily, at different elevations, sometimes from one thousand to three thousand feet above the level of the sea; and forty species or more in Ischia, partly from an elevation of above one thousand feet, and these were carefully compared with recent shells procured by Professor O. G. Costa, from the Neapolitan seas. Not only were the fossil species for the most part identical with those now living, but the relative abundance in which different species occur in the strata and in the sea corresponds in a remarkable manner. Yet the larger average size of the fossil individuals of many species was very striking. A comparison of the fossil shells of the more modern strata of Calabria and Otranto, in the collection of Professor Costa, afforded similar results.

As we proceed northwards in the Italian peninsula, and pass from the region of active to that of extinct volcanos, we find the assemblage of fossil shells, in the modern (Subapennine) strata, to depart somewhat more widely from the type of the neighbouring seas. The proportion of species identifiable with those now living in the Mediterranean is still considerable; but it no longer predominates, as in the South of Italy, over the unknown species. Although occurring in localities which are removed several degrees farther from the equator (as at Sienna, Parma, Asti, &c.), the shells yield clear indications of a hotter climate. Many

of them are common to the Subapennine hills, to the Mediterranean, and to the Indian Ocean. Those in the fossil state, and their living analogues from the tropics, correspond in size; whereas the individuals of the same species from the Mediterranean are dwarfish and appear degenerate, and stunted in their growth, for want of conditions which the Indian Ocean still supplies.*

This evidence is of great weight, and is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to arctic regions. Whenever any of the fossil shells are identified with living species foreign to the Mediterranean, it is not in the Northern Ocean, but between the tropics, that they must be sought†: on the other hand,

* Professors Guidotti of Parma, and Bonelli of Turin, pointed out to me, in 1828, many examples in confirmation of this point. Among others, I may mention that Bulla lignaria, a very common shell, is invariably found fossil in the north of Italy of the same magnitude as it now reaches in the Indian sea, and much smaller in a living state in the Mediterranean. Individuals, however, of this great size are said to have been found at La Rochelle. The common Orthoceras of the Mediterranean, O. raphanista, attains larger average dimensions in a fossil, than in a recent state.

† Thus, for example, Rostellaria curvirostris, found fossil by Signor Bonelli near Turin, is only known at present as an Indian shell. Murex cornutus, fossil at Asti, is now only known recent in warmer latitudes, the only localities given by Linnæus and Lamarck being the African and Great Indian Oceans. Senegal is the principal known habitat at present. Conus antediluvianus cannot be distinguished from a shell now brought from Owhyhee. Among other familiar instances mentioned to me by Italian naturalists, in confirmation of the same point, Buccinum

the associated unknown species belong, for the most part, to *genera* which are now most largely developed in equinoctial regions, as, for example, the genera Pleurotoma and Cypræa.*

On comparing the fossils of the tertiary deposits of Paris and London with those of Bordeaux, and these again with the more modern strata of Sicily, we should at first expect that they would each indicate a higher temperature in proportion as they are situated farther to the south. But the contrary is true; many shells are common to all these groups, and some of them, both freshwater and marine, are of species still living. Those found in the older, or Eocene deposits of Paris and London, although 6° or 7° N. of the Miocene strata at Bordeaux, afford evidence of a warmer climate; while those of Bordeaux imply that the sea in which they lived was of a higher temperature than that of Sicily, where the shelly strata were formed six or seven degrees nearer to the equator. In these cases the greater antiquity of the several formations (the Parisian being the oldest and the Sicilian the newest) has more than counterbalanced the influence which latitude would otherwise exert, and this phe-

clathratum, Lam., was cited; but Professor Costa assured me that this shell, although extremely rare, still occurs in the Mediterranean. M. Deshayes informs me that he has received it from the Indies.

* Of the genus Pleurotoma a very few living representatives have yet been found in the Mediterranean; yet no less than twenty-five species are now to be seen in the museum at Turin, all procured by Professor Bonelli from the Subapennine strata of northern Italy. The genus Cypræa is represented by many large fossil species in the Subapennine hills, with which are associated one small and two or three minute species of the same genus, now found in the Mediterranean.

nomena clearly points to a gradual refrigeration of climate.

Siberian Mammoths.—In the superficial deposits of sand, gravel, and loam, strewed very generally over all parts of Europe, the remains of extinct species of land quadrupeds have been found, especially in places where the alluvial matter appears to have been washed into small lakes, or into depressions in the plains bordering ancient rivers. Similar deposits have also been lodged in rents and caverns of rocks where they may have been swept in by land floods, or introduced by engulphed rivers during changes in the physical geography of countries. The various circumstances under which the bones of animals have been thus preserved will be more fully considered hereafter *; I shall only state here, that among the extinct mammalia thus entombed, we find species of the elephant, rhinoceros, hippopotamus, bear, hyæna, lion, tiger, and many others; consisting for the most part of genera now confined to warmer regions.

It has been inferred that the same change of climate which has caused certain Indian species of testacea to become rare, or to degenerate in size, or to disappear from the Mediterranean,—and certain genera of the Subapennine hills, now exclusively tropical, to retain no longer any representatives in the adjoining seas,—may also have contributed to the annihilation of the mammiferous genera which formerly inhabited the continents. It is certainly probable that, when these animals abounded in Europe, the climate was milder than that now experienced, but they by no means

* Book iii. chaps. 14, 15, &c.

appear to have required a tropical heat. The hippopotamus is now only met with in rivers where the temperature of the water is warm and nearly uniform, but the great fossil species of the same genus (*H. major*, Cuv.) certainly inhabited England when the testacea of our country were nearly the same as those now existing, and when the climate cannot be supposed to have been very hot. The bones of this animal have lately been found by Mr. Strickland, together with those of a bear and other mammalia, at Cropthorn, near Evesham, in Worcestershire, in alluvial sand, together with twenty-three species of terrestrial and freshwater shells, all, with two exceptions, of British species. The bed of sand, containing the shells and bones, reposes on lias, and is covered with alternating strata of gravel, sand and loam. *

The mammoth also appears to have existed in England when the temperature of our latitudes could not have been very different from that which now prevails; for remains of this animal have been found at North Cliff, in the county of York, in a lacustrine formation, in which all the land and freshwater shells, thirteen in number, can be identified with species and varieties now existing in that county. Bones of the bison also, an animal now inhabiting a cold or temperate climate, have been found in the same place. That these quadrupeds, and the indigenous species of testacea associated with them, were all contemporary inhabitants of Yorkshire, has been established by unequivocal proof. The Rev. W. V. Vernon Harcourt caused a pit to be sunk to the depth of twenty-two feet through undisturbed strata, in which the remains of the mammoth

* Geol. Proceedings, No. 36. June, 1834.

were found imbedded, together with the shells, in a deposit which had evidently resulted from tranquil waters.*

When reasoning on these phenomena, the reader must always bear in mind that the fossil individuals belonged to *species* of elephant, rhinoceros, hippopotamus, bear, tiger, and hyæna, distinct from those which now dwell within or near the tropics. Dr. Fleming, in a discussion on this subject, has well remarked that a near resemblance in form and osteological structure is not always followed, in the existing creation, by a similarity of geographical distribution; and we must therefore be on our guard against deciding too confidently, from mere analogy of anatomical structure, respecting the habits and physiological peculiarities of *species*, now no more. "The zebra delights to roam over the tropical plains, to which it is in a great measure restricted; while the horse can maintain its existence throughout an Iceland winter. The buffalo, like the zebra, prefers a high temperature, and cannot thrive even where the common ox prospers. The musk ox, on the other hand, though nearly resembling the buffalo, prefers the stinted herbage of the arctic regions, and is able, by its periodical migrations, to outlive a northern winter. The jackal (*Canis aureus*) inhabits Africa, the warmer parts of Asia, and Greece; while the isatis (*Canis lagopus*) resides in the arctic regions. The African hare and the polar hare have their geographical distribution expressed in their trivial names†;" and different species of bears thrive in tropical, temperate, and arctic latitudes.

* Phil. Mag., Sept. 1829 and Jan. 1830.

† Fleming, Ed. New Phil. Journ., No. 12. p. 282. 1829.

Recent investigations have placed beyond all doubt the important fact that a species of tiger, identical with that of Bengal, is common in the neighbourhood of Lake Aral, near Sussac, in the forty-fifth degree of north latitude; and from time to time this animal is now seen in Siberia, in a latitude as far north as the parallel of Berlin and Hamburgh.* Humboldt remarks that the part of southern Asia now inhabited by this Indian species of tiger is separated from the Himalaya by two great chains of mountains, each covered with perpetual snow,—the chain of Kuenlun, lat. 35° N., and that of Mouztagh, lat. 42°,—so that it is impossible that these animals should merely have made excursions from India, so as to have penetrated in summer to the forty-eighth and fifty-third degrees of north latitude. They must remain all the winter north of the Mouztagh, or Celestial Mountains. The last tiger killed, in 1828, on the Lena, in lat. $52\frac{1}{4}$°, was in a climate colder than that of Petersburgh and Stockholm.†

We learn from Mr. Hodgson's account of the mammalia of Nepal, that the tiger is sometimes found at the very edge of perpetual snow in the Himalaya‡; and Pennant mentions that it is found among the snows of Mount Ararat in Armenia.

A new species also of panther (*Felis irbis*), covered with long hair, has been discovered in Siberia, evidently inhabiting, like the tiger, a region north of the Celestial Mountains, which are in lat. 42°.§

The two-horned African rhinoceros occurs without the tropics at the Cape of Good Hope, in lat. 34°

* Humboldt, Fragmens de Géologie, &c., tome ii. p. 388. Ehrenberg, Ann. des Sci. Nat., tome xxi. p. 387.

† Ehrenberg, ibid. p. 390.

‡ Journ. of Asiat. Soc., vol. i. p. 240.

§ Ehrenberg, ibid.

29′ S., where it is accompanied by the elephant, hippopotamus, and hyæna. Here the migration of all these species towards the south is arrested by the ocean; but, if the continent had been prolonged still farther, and the land had been of moderate elevation, it is very probable that they might have extended their range to a greater distance from the tropics.

Now, if the Indian tiger can range in our own times to the southern borders of Siberia, or skirt the snows of the Himalaya, we may easily imagine that large species of the same genus may once have inhabited our temperate climates. The mammoth (*E. primigenius*), already alluded to as occurring fossil in England, was decidedly different from the two existing species of elephants, one of which is limited to Asia, south of the 31° of N. lat., the other to Africa, where it extends, as before stated, as far south as the Cape of Good Hope. The bones of the great fossil species are very widely spread over Europe and North America; but are nowhere in such profusion as in Siberia, particularly near the shores of the frozen ocean. Are we, then, to conclude that this animal preferred a polar climate? If so, by what food was it sustained, and why does it not still survive near the arctic circle?

Pallas and other writers describe the bones of the mammoth as abounding throughout all the Lowland of Siberia, stretching in a direction west and east, from the borders of Europe to the extreme point nearest America, and south and north, from the base of the mountains of central Asia to the shores of the arctic sea. Within this space, scarcely inferior in area to the whole of Europe, fossil ivory has been collected almost every where, on the banks of the Irtish, Oby, Yenesei, Lena, and other rivers. The elephan-

tine remains do not occur in the marshes and low plains, but where the banks of the rivers present lofty precipices of sand and clay; from which circumstance Pallas very justly inferred that, if sections could be obtained, similar bones might be found in all the elevated lands intervening between the great rivers. Strahlenberg, indeed, had stated, before the time of Pallas, that wherever any of the great rivers overflowed and cut out fresh channels during floods, more fossil remains of the same kind were invariably disclosed.

As to the position of the bones, Pallas found them in some places imbedded together with marine remains; in others, simply with fossil wood, or lignite, such, as he says, might have been derived from carbonized peat. On the banks of the Yenesei, below the city of Krasnojarsk, in lat. 56°, he observed grinders, and bones of elephants, in strata of yellow and red loam, alternating with coarse sand and gravel, in which was also much petrified wood of the willow and other trees. Neither here nor in the neighbouring country were there any marine shells, but merely layers of black coal.* But grinders of the mammoth were collected much farther down the same river, near the sea, in lat. 70°, mixed with *marine* petrifactions.† Many other places in Siberia are cited by Pallas, where sea shells and fishes' teeth accompany the bones of the mammoth, rhinoceros, and Siberian buffalo, or bison (*Bos priscus*). But it is not on the Oby nor the Yenesei, but on the Lena, farther to the east, where, in the same parallels of latitude, the cold is far more intense, that fossil remains have been found in the most wonderful state of preservation. In 1772, Pallas obtained from Wiljuiskoi, in lat. 64°, from the banks of

* Pallas, Reise in Russ. Reiche, pp. 409, 410.

† Nov. Com. Petrop. vol. 17. p. 584.

the Wiljui, a tributary of the Lena, the carcass of a rhinoceros (*R. tichorhinus*), taken from the sand in which it must have remained congealed for ages, the soil of that region being always frozen to within a slight depth of the surface. This carcass was compared to a natural mummy, and emitted an odour like putrid flesh, part of the skin being still covered with black and gray hairs. So great, indeed, was the quantity of hair on the foot and head conveyed to St. Petersburg, that Pallas asked whether the rhinoceros of the Lena might not have been an inhabitant of the temperate regions of middle Asia, its clothing being so much warmer than that of the African rhinoceros.* After more than 30 years, the entire carcass of a mammoth was obtained in 1803, by Mr. Adams, much farther to the north. It fell from a mass of ice, in which it had been encased, on the banks of the Lena, in lat. 70° ; and so perfectly had the soft parts of the carcass been preserved, that the flesh, as it lay, was devoured by wolves and bears. This skeleton is still in the museum of St. Petersburg, the head retaining its integument and many of the ligaments entire. The skin of the animal was covered, first, with black bristles, thicker than horse hair, from twelve to sixteen inches in length; secondly, with hair of a reddish brown colour, about four inches long; and thirdly, with wool of the same colour as the hair, about an inch in length. Of the fur, upwards of thirty pounds' weight were gathered from the wet sand-bank. The individual was nine feet high, and sixteen feet long, without reckoning the large curved tusks; a size rarely surpassed by the largest living male elephants. †

* Nov. Com. Petrop. vol. 17. p. 591.

† Journal du Nord, St. Petersburg, 1807.

It is evident, then, that the mammoth, instead of being naked, like the living Indian and African elephants was enveloped in a thick shaggy covering of fur, probably as impenetrable to rain and cold as that of the musk ox.* The species may have been fitted by nature to withstand the vicissitudes of a northern climate; and it is certain that, from the moment when the carcasses, both of the rhinoceros and elephant, above described, were buried in Siberia, in latitudes 64° and 70° N., the soil must have remained frozen, and the atmosphere nearly as cold as at this day.

* Fleming, Ed. New Phil. Journ., No. xii., p. 285.

Bishop Heber informs us (Narr. of a Journey through the Upper Provinces of India, vol. ii. p. 166—219.), that in the lower range of the Himalaya mountains, in the north-eastern borders of the Delhi territory, between lat. 29° and 30°, he saw an Indian elephant of a small size, covered with shaggy hair. But this variety must be exceedingly rare; for Mr. Royle (late superintendant of the East India Company's Botanic Garden at Saharunpore) has assured me, that being in India when Heber's Journal appeared, and having never seen or heard of such elephants, he made the strictest inquiries respecting the fact, and was never able to obtain any evidence in corroboration. Mr. Royle resided at Saharunpore, lat. 30° N., upon *the extreme northern limit* of the range of the elephant. Mr. Everest also declares that he has been equally unsuccessful in finding any one aware of the existence of such a variety or breed of the animal, though one solitary individual was mentioned to him as having been seen at Delhi, with a good deal of long hair upon it. The greatest elevation, says Mr. E., at which the wild elephant is found in the mountains to the north of Bengal, is at a place called Nahun, about 4000 feet above the level of the sea, and in the 31st degree of N. lat., where the mean yearly temperature may be about 64° Fahrenheit, and the difference between winter and summer very great, equal to about 36° F., the month of January averaging 45°, and June, the hottest month, 81° F. (Everest on Climate of Foss. Eleph., Journ. of Asiat. Soc., No. 25, p. 21.)

So fresh is the ivory throughout northern Russia, that, according to Tilesius, thousands of fossil tusks have been collected and used in turning; yet others are still procured and sold in great plenty. He declares his belief that the bones still left in northern Russia must greatly exceed in number all the elephants now living on the globe.

We are as yet ignorant of the entire geographical range of this fossil mammoth; but its remains have recently been collected from cliffs of frozen mud and ice on the east side of Behring's Straits, in Eschscholtz's Bay, in Russian America, lat. 66° N. As the cliffs waste away by the thawing of the ice, tusks and bones fall out, and a strong odour of animal matter is exhaled from the mud.*

On considering all the facts above enumerated, it seems reasonable to imagine that a large region in central Asia, including, perhaps, the southern half of Siberia, enjoyed, at no very remote period in the earth's history, a temperate climate, sufficiently mild to afford food for large herds of elephants and rhinoceroses, *of species distinct from those now living.* At the time to which these speculations refer, the Lowland of Siberia was probably less extensive towards the north than it is now; but the existing rivers, though of inferior length, may have flowed from south to north, as at present, and, during inundations, may have swept the carcasses of drowned animals into lakes, or the sea, as do the Nile, Ganges, and other rivers in our own time.†

In Siberia all the principal rivers are liable, like the

* See Dr. Buckland's description of these bones, Appen. to Beechey's Voy.

† See Book iii. chaps. xv. and xvi.

Mackenzie, in North America, to remarkable floods, in consequence of flowing in a direction from south to north; for they are filled with running water in their upper course when completely frozen over for several hundred miles near their mouths. Here they remain blocked up by ice for six months in every year, and the descending waters, finding no open channel, rush over the ice; often changing their direction; and sweeping along forests and prodigious quantities of soil and gravel mixed with ice. The rivers of this great country are among the largest in the world, the Yenesei having a course of 2500, the Lena of 2000 miles; so that we may easily conceive that the bodies of animals which fall into their waters may be transported to vast distances towards the arctic sea, and, before arriving there, may be stranded upon thick ice, and afterwards, when the ice breaks up, be floated still farther towards the ocean, until at length they become buried in fluviatile and submarine deposits near the mouths of rivers.

It would doubtless be impossible for herds of mammoths and rhinoceroses to obtain subsistence at present, even in the southern part of Siberia, covered as it is during a great part of the year with snow: but there is no difficulty in supposing a vegetation capable of nourishing these great quadrupeds to have once flourished between the latitudes 40° and 60° N., resembling perhaps that of England; for we have seen that there are proofs of the mammoth having coexisted with a large proportion of the living species of British testacea.

It has been well observed by Dr. Fleming, that "the kind of food which the existing species of elephant prefers will not enable us to determine, or even to

offer a probable conjecture, concerning that of the extinct species. No one acquainted with the gramineous character of the food of our fallow-deer, stag, or roe, would have assigned a lichen to the reindeer."

Travellers mention that, even now, when the climate of eastern Asia is so much colder than the same parallels of latitude farther west, there are woods not only of fir, but of birch, poplar, and alder on the banks of the Lena as far north as latitude 60°. Formerly, when the arctic lands were less extensive, the temperature of the winter and summer may have been more nearly equalized, and the increasing severity of the winters, rather than a diminution of the mean annual temperature, may have been the chief cause of the extermination of the mammoth. It is probable that the refrigeration of the climate of north-eastern Asia was accompanied, and in a great measure caused, by changes in its physical geography. The whole country, from the mountains to the sea, may have been upraised by a movement similar to that which is now experienced in part of Sweden; and as the shores of the Gulf of Bothnia are extended not only by the influx of sediment brought down by rivers, but also by the elevation and consequent drying up of the bed of the sea, so a similar combination of causes may have extended the low tract of land where marine shells and fossil bones now occur in Siberia.

It has been suggested, that as, in our own times, the northern animals migrate, so the Siberian elephant and rhinoceros may have wandered towards the north in summer. The musk oxen annually desert their winter quarters in the south, and cross the sea upon the ice, to graze for four months, from May to Sep-

tember, on the rich pasturage of Melville Island, in lat. 75°. The mammoths, without passing so far beyond the arctic circle, may nevertheless have made excursions, during the heat of a brief northern summer, from the central or temperate parts of Asia to the sixtieth parallel of latitude; in which case the carcasses of such as were drowned, or overwhelmed by drift snow, may have been hurried down into the polar sea, and imbedded in the deposits there accumulating.

I have been informed by Dr. Richardson, that in the northern parts of America, comprising regions now inhabited by many herbivorous quadrupeds, the drift snow is often converted into permanent glaciers. It is commonly blown over the edges of steep cliffs, so as to form an inclined talus hundreds of feet high; and when a thaw commences, torrents rush from the land, and throw down from the top of the cliff alluvial soil and gravel. This new soil soon becomes covered with vegetation, and protects the foundation of snow from the rays of the sun. Water occasionally penetrates into the crevices and pores of the snow; but, as it soon freezes again, it serves the more rapidly to consolidate the mass into a compact iceberg. It may sometimes happen that cattle grazing in a valley at the base of such cliffs, on the borders of a sea or river, may be overwhelmed, and at length enclosed in solid ice, and then transported towards the polar regions.

The result of these investigations, therefore, may lead us to conclude that the mammoth, and some other extinct quadrupeds fitted to live in high latitudes, were inhabitants of northern Asia at a time when the climate was milder, and more uniform, than at present. Their extirmination was probably connected with changes in the physical geography of the arctic re-

gions, of which I shall consider the effects in the next chapter.

Change of climate proved by fossils in older strata.—If we pass from the consideration of these more modern deposits, whether of marine or continental origin, in which existing species are abundantly intermixed with the extinct, to the older tertiary strata, we can only reason from analogy; since none of the species of vertebrated animals, and scarcely any of the testacea of those formations, are identifiable with species now in being. In the deposits of that more remote period, we find the remains of many animals analogous to those of hot climates, such as the crocodile, turtle, and tortoise, together with many large shells of the genus nautilus, and plants indicating such a temperature as is now found along the southern borders of the Mediterranean.

A great interval of time appears to have elapsed between the formation of the secondary strata, which constitute the principal portion of the elevated land in Europe, and the origin of the last-mentioned Eocene deposits. In that great series of secondary rocks, many distinct assemblages of organized fossils are entombed, all of unknown species, and many of them referrible to genera and families now most abundant between the tropics. Among the most remarkable are many gigantic reptiles, some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmer parts of the earth. Coral reefs also were evidently numerous in the seas of the same periods, and composed of species belonging to genera now charac-

teristic of a tropical climate. The number of very large chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the Cycadeæ constituting the most numerous family.

But it is from the more ancient coal deposits that the most extraordinary evidence has been supplied in proof of the former existence of an extremely hot climate in those latitudes which are now the temperate and colder regions of the globe. It appears from the fossils of the carboniferous period, that the flora consisted almost exclusively of large vascular cryptogamic plants. We learn, from the labours of M. Ad. Brongniart, that there existed at that epoch Equiseta upwards of ten feet high, and from five to six inches in diameter; tree ferns, or plants allied to them, from forty to fifty feet in height, and arborescent Lycopodiaceæ, from sixty to seventy feet high.* Of the above classes of vegetables, the species are all small at present in cold climates; while in tropical regions there occur, together with small species, many of a much greater size, but their development, even in the hottest parts of the globe, is now inferior to that indicated by the petrified forms of the coal formation. An elevated and uniform temperature, and great humidity in the air, are the causes most favourable to the numerical predominance and the great size of these plants within the torrid zone at present. It is true that, as the fossil flora consists of such plants as may accidentally have been floated into seas, lakes, or estuaries, it may very commonly give a false representation of the numerical relations of families then living on the land. Yet, after

* Consid. Générales sur la Nature de la Végétation, &c. Ann. des Sci. Nat., Nov. 1828.

allowing for liability to error on these grounds, the argument founded on the comparative numbers of the fossil plants of the carboniferous strata is very strong.

"In regard to the geographical extent of the ancient vegetation, it was not confined," says M. Brongniart, "to a small space, as to Europe, for example; for the same forms are met with again at great distances. Thus, the coal plants of North America are, for the most part, identical with those of Europe, and all belong to the same genera. Some specimens, also, from Greenland, are referrible to ferns, analogous to those of our European coal mines." *

The fossil plants brought from Melville Island, although in a very imperfect state, have been supposed to warrant similar conclusions †; and assuming that they agree with those of Baffin's Bay, mentioned by M. Brongniart, how shall we explain the manner in which such a vegetation lived through an arctic night of several months' duration? ‡

This point has of late been dwelt upon by Professor Lindley, as one of considerable difficulty §; and he is even inclined to resort again to the favourite hypothesis of earlier theorists — a derangement in the position of

* Prodrome d'une Hist. des Végét. Foss. p. 179.

† König, Journ. of Sci. vol. xv. p. 20. Mr. König informs me, that he no longer believes any of these fossils to be tree ferns, as he at first stated, but that they agree with tropical forms of plants in our English coal-beds. The Melville Island specimens, now in the British Museum, are very obscure impressions.

‡ Fossil Flora of Great Britain, by John Lindley and William Hutton, Esqrs. No. IV.

§ Fossil Flora, No. IV.; and in his Lectures. Mr. Lindley tells me, however, that he has not yet (Oct. 1833) had opportunities of examining the fossil plants of high latitudes.

the earth's axis of rotation. But all astronomers are agreed that speculations on such a change are inadmissible, as being incompatible with the laws of equilibrium. Even if a catastrophe, such as the collision of a comet, be called in, and admitted as adequate to alter the obliquity of the axis, the problem is by no means solved; for in that case the seas would have all rushed to the new equator, and would probably still be insufficient to restore equilibrium.*

It may seem premature to discuss the question now raised, until the true nature of the fossil flora of the arctic regions has been more accurately determined; yet, as the question has attracted some attention, let us assume for a moment, that the coal plants of Melville Island are strictly analogous to those of Northumberland — would such a fact present an inexplicable enigma to the vegetable physiologist?

Plants, it is affirmed, cannot remain in darkness, even for a week, without serious injury, unless in a torpid state; and if exposed to heat and moisture they cannot remain torpid, but will grow, and must therefore perish. If, then, in the latitude of Melville Island, 75° N., a high temperature, and consequent humidity, prevailed at that period when we know the arctic seas were filled with corals and large multilocular shells, how could plants of tropical forms have flourished? Is not the bright light of equatorial regions as indispensable a condition of their well-being as the sultry heat of the same countries? and how could they annually endure a night prolonged for three months? †

Now, we must bear in mind, in the first place, that,

* Mrs. Somerville's Mech. of Heavens, Prel. Disc. p. 38.

† Fossil Flora, No. IV.

so far as experiments have been made, there is every reason to conclude, that the range of intensity of light to which living plants can accommodate themselves is far wider than that of heat. No palms or tree ferns can live in our temperate latitudes without protection from the cold; but when placed in hot-houses they grow luxuriantly, even under a cloudy sky, and where much light is intercepted by the glass and frame-work. At St. Petersburg, in lat. 60° N., these plants have been successfully cultivated in hot-houses, although there they must exchange the perpetual equinox of their native regions for days and nights which are alternately protracted to nineteen hours and shortened to five. How much farther towards the pole they might continue to live, provided a due quantity of heat and moisture were supplied, has not yet been determined; but St. Petersburg is probably not the utmost limit, and we should expect that in lat. 65° at least, where they would never remain twenty-four hours without enjoying the sun's light, they might still exist.

Nor must we forget that we are always speaking of *living* species formed to inhabit within or near the tropics. The coal plants were of perfectly distinct species, and may have been endowed with a different constitution, enabling them to bear a greater variation of circumstances in regard to light. We find that particular species of palms and tree ferns require at present different degrees of heat; and that some species can thrive only in the immediate neighbourhood of the equator, others only at a distance from it. In the same manner the *minimum* of *light*, sufficient for the now existing species, cannot be taken as the standard

for all analogous tribes that may ever have flourished on the globe.

But granting that the extreme northern point to which a flora like that of the carboniferous era could ever reach may be somewhere between the latitudes of 65° and 70°, we should still have to inquire whether the vegetable remains might not have been drifted from thence, by rivers and currents, to the parallel of Melville Island, or still farther. In the northern hemisphere, at present, we see that the materials for future beds of lignite and coal are becoming amassed in high latitudes, far from the districts where the forests grew, and on shores where scarcely a stunted shrub can now exist. The Mackenzie, and other rivers of North America, carry pines with their roots attached for many hundred miles towards the north, into the arctic sea, where they are imbedded in deltas, and some of them drifted still farther by currents towards the pole.

Some of the appearances of our English coal fields seem to prove that the plants were not floated from great distances; for the outline of the stems of succulent species preserve their sharp angles, and others have their surfaces marked with the most delicate lines and streaks. Long leaves, also, are attached in many instances to the trunks or branches *; and leaves we know, in general, are soon destroyed when steeped in water, although ferns will retain their forms after an immersion of several months.† It seems fair to presume that the coal plants may have grown upon the same land, the destruction of which provided materials for the sandstones and conglomerates of the group of

* Fossil Flora, No. X.

† This has been proved by Mr. Lindley, who is now conducting a series of experiments on the subject.

strata in which they are imbedded; especially as the coarseness of the particles of many of these rocks attests that they were not borne from very remote localities.

Before we are entitled to enlarge farther on this question of transportation, we must obtain more precise information respecting the state of the various fossils which have been found principally in the coal sandstones of high latitudes, and we must learn whether they bear the marks of friction and decay previous to their fossilization.

To return, therefore, from this digression, the uninjured corals and chambered univalves of Igloolik (lat. $69\frac{1}{3}°$ N.), Melville Island, and other high latitudes, sufficiently prove that, during the carboniferous period, there was an elevated temperature even in northern regions bordering on the arctic circle. The heat and humidity of the air, and the uniformity of climate, appear to have been most remarkable when the oldest strata hitherto discovered were formed. The approximation to a climate similar to that now enjoyed in these latitudes does not commence till the era of the formations termed tertiary; and while the different tertiary rocks were deposited in succession, the temperature seems to have been still further lowered, and to have continued to diminish gradually, even after the appearance upon the earth of a great portion of the existing species.

CHAPTER VII.

FARTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

On the causes of vicissitudes in climate — Remarks on the present diffusion of heat over the globe — On the dependence of the mean temperature on the relative position of land and sea — Isothermal lines — Currents from equatorial regions (p. 165). — Drifting of icebergs — Different temperature of Northern and Southern hemispheres — Combination of causes which might produce the extreme cold of which the earth's surface is susceptible (p. 181). — Conditions necessary for the production of the extreme of heat, and its probable effects on organic life (p. 189).

Causes of vicissitudes in Climate. — As the proofs enumerated in the last chapter indicate that the earth's surface has experienced great changes of climate since the deposition of the older sedimentary strata, we have next to inquire, how such vicissitudes can be reconciled with the existing order of nature. The cosmogonist has availed himself of this, as of every obscure problem in geology, to confirm his views concerning a period when the laws of the animate and inanimate world differed essentially from those now established; and he has in this, as in many other cases, succeeded so far, as to divert attention from that class of facts, which, if fully understood, might probably lead to an explanation of the phenomena. At first it was imagined that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a

perpetual equinox, and uniformity of seasons throughout the year; — that the planet enjoyed this 'paradisiacal' state until the era of the great flood; but in that catastrophe, whether by the shock of a comet, or some other convulsion, it lost its equal poise, and hence the obliquity of its axis, and with that the varied seasons of the temperate zone, and the long nights and days of the polar circles.

When the progress of astronomical science had exploded this theory, it was assumed, that the earth at its creation was in a state of fluidity, and red hot, and that ever since that era it had been cooling down, contracting its dimensions, and acquiring a solid crust, — an hypothesis hardly less arbitrary, but more calculated for lasting popularity, because, by referring the mind directly to the beginning of things, it requires no support from observation, nor from any ulterior hypothesis. They who are satisfied with this solution are relieved from all necessity of inquiry into the present laws which regulate the diffusion of heat over the surface; for, however well these may be ascertained, they cannot possibly afford a full and exact elucidation of the internal changes of an embryo world.

But if, instead of forming vague conjectures as to what might have been the state of the planet at the era of its creation, we fix our thoughts on the connexion at present existing between climate and the distribution of land and sea; and then consider what influence former fluctuations in the physical geography of the earth must have had on superficial temperature, we may perhaps approximate to a true theory. If doubts and obscurities still remain, they should be ascribed to our limited acquaintance with the laws of Nature, not to revolutions in her economy; — they

should stimulate us to further research, not tempt us to indulge our fancies in framing imaginary systems for the government of infant worlds.

Diffusion of heat over the globe.—In considering the laws which regulate the diffusion of heat over the globe, we must be careful, as Humboldt well remarks, not to regard the climate of Europe as a type of the temperature which all countries placed under the same latitude enjoy. The physical sciences, observes this philosopher, always bear the impress of the places where they began to be cultivated; and as, in geology, an attempt was at first made to refer all the volcanic phenomena to those of the volcanos in Italy, so, in meteorology, a small part of the old world, the centre of the primitive civilization of Europe, was for a long time considered a type to which the climate of all corresponding latitudes might be referred. But this region, constituting only one seventh of the whole globe, proved eventually to be the exception to the general rule. For the same reason, we may warn the geologist to be on his guard, and not hastily to assume that the temperature of the earth in the present era is a type of that which most usually obtains, since he contemplates far mightier alterations in the position of land and sea, at different epochs, than those which now cause the climate of Europe to differ from that of other countries in the same parallels.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other.* It is also known that the *mean* annual

* We are indebted to Baron Alex. Humboldt for collecting together, in a beautiful essay, the scattered data on which he

temperature may be the same in two places which enjoy very different climates, for the seasons may be nearly uniform, or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat, or isothermal lines. The deviations of all these lines from the same parallel of latitude are determined by a multitude of circumstances, among the principal of which are the position, direction, and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

On comparing the two continents of Europe and America, it is found that places in the same latitudes have sometimes a mean difference of temperature amounting to 11°, or even in a few cases to 17° Fahr.; and some places on the two continents, which have the same mean temperature, differ from 7° to 13° in latitude.† The principal cause of greater intensity of cold in corresponding latitudes of North America and Europe, is the connexion of North America with the polar circle, by a large tract of land, some of which is from three to five thousand feet in height, and, on the other hand, the separation of Europe from the arctic circle by an ocean. The ocean has a tendency to preserve every where a mean temperature, which it communicates to the contiguous land, so that it tempers the climate, moderating alike an excess of heat or cold.

founded an approximation to a true theory of the distribution of heat over the globe. Many of these data are derived from the author's own observations, and many from the works of M. Pierre Prevost, of Geneva, on the radiation of heat, and other writers.— See Humboldt on Isothermal Lines, Mémoires d'Arcueil, tom. iii. translated in the Edin. Phil. Journ. vol. iii. July, 1820.

† Humboldt's tables, Essay on Isothermal Lines, &c.

The elevated land, on the other hand, rising to the colder regions of the atmosphere, becomes a great reservoir of ice and snow, arrests, condenses, and congeals vapour, and communicates its cold to the adjoining country. For this reason, Greenland, forming part of a continent which stretches northward to the 82d degree of latitude, experiences under the 60th parallel a more rigorous climate than Lapland under the 72d parallel.

But if land be situated between the 40th parallel and the equator, it produces, unless it be of extreme height, exactly the opposite effect; for it then warms the tracts of land or sea that intervene between it and the polar circle. For the surface being in this case exposed to the vertical, or nearly vertical rays of the sun, absorbs a large quantity of heat, which it diffuses by radiation into the atmosphere. For this reason, the western parts of the old continent derive warmth from Africa, "which, like an immense furnace, distributes its heat to Arabia, to Turkey in Asia, and to Europe." * On the contrary, the north-eastern extremity of Asia experiences in the same latitude extreme cold; for it has land on the north between the 60th and 70th parallel, while to the south it is separated from the equator by the North Pacific.

In consequence of the more equal temperature of the waters of the ocean, the climate of islands and of coasts differs essentially from that of the interior of continents, the more maritime climates being characterized by mild winters and more temperate summers; for the sea breezes moderate the cold of winter, as well as the heat of summer. When, therefore, we

* Malte-Brun. Phys. Geog. book xvii.

trace round the globe those belts in which the mean annual temperature is the same, we often find great differences in climate; for there are *insular* climates in which the seasons are nearly equalized, and *excessive* climates, as they have been termed, where the temperature of winter and summer is strongly contrasted. The whole of Europe, compared with the eastern parts of America and Asia, has an insular climate. The northern part of China, and the Atlantic region of the United States, exhibit "excessive climates." We find at New York, says Humboldt, the summer of Rome and the winter of Copenhagen; at Quebec, the summer of Paris and the winter of Petersburg. At Pekin, in China, where the mean temperature of the year is that of the coasts of Brittany, the scorching heats of summer are greater than at Cairo, and the winters as rigorous as at Upsala.*

If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much farther than the lines of equal mean annual heat. The lines of equal winter in Europe, for example, are often curved so as to reach parallels of latitude 9° or 10° distant from each other, whereas the isothermal lines, or those passing through places having the same mean annual temperature, differ only from 4° to 5°.

Influence of currents on temperature.—Among other influential causes, both of remarkable diversity in the mean annual heat, and of unequal division of heat in the different seasons, are the direction of currents and the accumulation and drifting of ice in high latitudes. The temperature of the Lagullas current is 10° or 12°

* On Isothermal Lines, &c.

Fahr. above that of the sea at the Cape of Good Hope; for the greater part of its waters flow through the Mozambique channel, down the south-east coast of Africa, and are derived from regions in the Indian Ocean much nearer the line, and much hotter than the Cape.* An opposite effect is produced by the "equatorial" current, which crosses the Atlantic from Africa to Brazil, having a breadth varying from 160 to 450 nautical miles. Its waters are cooler by 3° or 4° Fahr. than those of the ocean under the line, so that it moderates the heat of the tropics.†

But the effects of the Gulf stream on the climate of the north Atlantic Ocean are far more remarkable. This most powerful of known currents has its source in the Gulf or Sea of Mexico, which, like the Mediterranean and other close seas in temperate or low latitudes, is warmer than the open ocean in the same parallels. The temperature of the Mexican sea in summer is, according to Rennell, 86° Fahr. or at least 7° above that of the Atlantic in the same latitude.‡ From this great reservoir or caldron of warm water, a constant current pours forth through the straits of Bahama at the rate of 3 or 4 miles an hour; it crosses the ocean in a north-easterly direction, skirting the great bank of Newfoundland, where it still retains a temperature of 8° above that of the surrounding sea. It reaches the Azores in about 78 days, after flowing nearly 3000 geographical miles, and from thence it sometimes extends its course a thousand miles further, so as to reach the Bay of Biscay, still retaining an excess of 5° above the mean temperature of that sea. As it has been known to

* Rennell on Currents, p. 96. London, 1832.

† Ibid. p. 153.

‡ Ibid. p. 25.

arrive there in the months of November and January, it may tend greatly to moderate the cold of winter in countries on the west of Europe.

There is a large tract in the centre of the North Atlantic, between the parallels of 33° and 35° N. lat. which Rennell calls the "recipient of the gulf water." A great part of it is covered by the weed called sargasso, which the current floats in abundance from the Gulf of Mexico. This mass of water is nearly stagnant, is warmer by 7° or 10° than the waters of the Atlantic, and may be compared to the fresh water of a river overflowing the heavier salt water of the sea. Rennell estimates the area of the "recipient," together with that covered by the main current, as being 2000 miles in length from E. to W., and 350 in breadth from N. to S., which, he remarks, is a larger area than that of the Mediterranean. The heat of this great body of water is kept up by the incessant and quick arrival of fresh supplies of warm water from the south, and there can be no doubt that the general climate of parts of Europe and America are materially affected by this cause.

It is considered probable by Scoresby, that the influence of the gulf stream extends even to the sea, near Spitzbergen, where its waters may pass under those of melted ice; for it has been found that, in the neighbourhood of Spitzbergen, the water is warmer by 6° or 7° at the depth of one hundred and two hundred fathoms than at the surface. This might arise from the known law that fresh water passes the point of greatest density when cooled down below 40°, and between that and the freezing point expands again. The water of melted ice might be lighter, both as being fresh (having lost its salt in the decomposing

process of freezing), and because its temperature is nearer the freezing point than the inferior water of the gulf stream.*

The great glaciers generated in the valleys of Spitzbergen, in the 79° of north latitude, are almost all cut off at the beach, being melted by the feeble remnant of heat still retained by the gulf stream. In Baffin's Bay, on the contrary, on the west coast of Old Greenland, where the temperature of the sea is not mitigated by the same cause, and where there is no warmer under-current, the glaciers stretch out from the shore, and furnish repeated crops of mountainous masses of ice which float off into the ocean.† The number and dimensions of these bergs is prodigious. Captain Ross saw several of them together in Baffin's Bay aground in water fifteen hundred feet deep! Many of them are driven down into Hudson's Bay, and accumulating there, diffuse excessive cold over the neighbouring continent; so that Captain Franklin reports, that at the mouth of Hayes river, which lies in the same latitude as the north of Prussia or the south of Scot-

* When Scoresby wrote in 1820 (Arctic Regions, vol. i. p. 210.), he doubted whether salt water expanded like fresh water when freezing. Since that time Erman (Poggendorf's Annalen, 1828, vol. xii. p. 483.) has proved by experiment that sea-water does not follow the same law as fresh water, as De Luc, Rumford, and Marcet had supposed. On the contrary, it appears that salt water of sp. gr. 1·027 (which according to Berzelius is the mean density of sea water) has *no maximum of density* so long as it remains fluid; and even when ice begins to form in it, the remaining fluid part always increases in density in proportion to the degree of refrigeration.

† Scoresby's Arctic Regions, vol. i. p. 208.—Dr. Latta's Observations on the Glaciers of Spitzbergen, &c. Edin. New Phil. Journ. vol. iii. p. 97.

land, ice is found every where in digging wells, in summer, at the depth of four feet! Other bergs are occasionally met with, in a state of rapid thaw, as far south as lat. 40°, off the eastern coast of Greenland, where they cool the water sensibly to the distance of forty or fifty miles around, the thermometer sinking sometimes 17°, or even 18°, Fahrenheit in their neighbourhood.*

Difference of climate of the Northern and Southern hemispheres. — When we compare the climate of the northern and southern hemispheres, we obtain still more instruction in regard to the influence of the distribution of land and sea on climate. The dry land in the southern hemisphere is to that of the northern in the ratio only of one to three, excluding from our consideration that part which lies between the pole and the 74° of south latitude, which has hitherto proved inaccessible. And whereas, in the northern hemisphere, between the pole and the thirtieth parallel of north latitude, the land and sea occupy nearly equal areas, the ocean in the southern hemisphere covers no less than fifteen parts in sixteen of the entire space included between the antarctic circle and the thirtieth parallel of south latitude.

This great extent of sea gives a particular character to climates south of the equator, the winters being mild and the summers cool. Thus, in Van Diemen's land, corresponding nearly in latitude to Rome, the winters are more mild than at Naples, and the summers not warmer than those at Paris, which is 7° farther from the equator.† The effect on vegetation is very

* Rennell on Currents, p. 95.

† Humboldt on Isothermal Lines.

remarkable:—tree-ferns, for instance, which require abundance of moisture, and an equalization of the seasons, are found in Van Diemen's land, in latitude 42° S.; and in New Zealand in south latitude 45°. The orchideous parasites also advance to the 38° and 42° of south latitude. Humboldt observes that it is in the *mountainous*, *temperate*, *humid*, and *shady* parts of the equatorial regions, that the family of ferns produces the greatest number of species. As we know, therefore, that elevation often compensates for the effect of latitude in the geographical distribution of plants, we may easily understand that a class of vegetables, which grow at a certain height in the torrid zone, would flourish on the plains at greater distances from the equator, if the temperature, moisture, and other necessary conditions, were equally uniform throughout the year.

It has long been supposed that the general temperature of the southern hemisphere was considerably lower than that of the northern, and that the difference amounted to at least 10° Fahrenheit. Baron Humboldt, after collecting and comparing a great number of observations, came to the conclusion that even a much larger difference existed, but that none was to be observed within the tropics, and only a small difference as far as the thirty-fifth and fortieth parallel. Captain Cook was of opinion that the ice of the antarctic predominated greatly over that of the arctic region, that encircling the southern pole coming nearer to the equator by 10° than the ice around the north pole. But the recent voyages of Weddell and Biscoe have shewn that on certain meridians it is possible to approach the south pole nearer by several degrees than Cook had penetrated; and even in the seventy-third and

seventy-fourth degrees of south latitude, they found the sea open and with few ice-floes.*

Nevertheless, the greater cold of high southern latitudes is confirmed by the description given both by ancient and modern navigators of the lands in this hemisphere. In Sandwich land, according to Cook, in 59° of south latitude, the perpetual snow and ice reach to the sea beach ; and what is still more astonishing, in the island of Georgia, which is in the 54° south latitude, or the same parallel as Yorkshire, the line of perpetual snow descends to the level of the ocean. When we consider this fact, and then recollect that the summit of the highest mountains in Scotland, four degrees farther to the north, do not attain the limit of perpetual snow on our side of the equator, we learn that latitude is one only of many powerful causes, which determine the climate of particular regions of the globe. The permanence of snow in the southern hemisphere, is in this instance partly due to the floating ice, which chills the atmosphere and condenses the vapour, so that in summer the sun cannot pierce through the foggy air. But besides the abundance of ice which covers the sea to the south of Georgia and Sandwich land, we may also, as Humboldt

* Captain Weddell, in 1823, advanced 3° farther than Captain Cook, and arrived at lat. 74° 15′ south, long. 34° 17′ west. After having passed through a sea strewed with numerous ice islands, he arrived, in that high latitude, at an open ocean ; but even if he had sailed 6° farther south, he would not have penetrated to higher latitudes than Captain Parry in the arctic circle, who reached lat. 81° 12′ 51″ north. Captain Biscoe, in 1831 and 1832, discovered Graham's Land between 64° and 68° S. lat., to the southward of New South Shetland, and Enderby's Land in the same latitude, on the meridian of Madagascar. Journ. of Roy. Geograph. Soc. of London, 1833, p. 105.

suggests, ascribe the cold of those countries in part to the absence of land between them and the tropics.

If Africa and New Holland extended farther to the south, a diminution of ice would take place in consequence of the radiation of heat from these continents during summer, which would warm the contiguous sea and rarefy the air. The heated aerial currents would then ascend and flow more rapidly towards the south pole, and moderate the winter. In confirmation of these views, it is stated that the ice, which extends as far as the 68° and 71° of south latitude, advances more towards the equator whenever it meets an open sea; that is, where the extremities of the present continents are not opposite to it; and this circumstance seems explicable only on the principle above alluded to, of the radiation of heat from the lands so situated.

The cold of the antarctic regions was conjectured by Cook to be due to the existence of a large tract of land between the seventieth degree of south latitude and the pole; and it is worthy of observation, that even now, after the most recent voyages, the area of land still unexplored within the antarctic circle is far more than double the area of Europe.* Some geographers think that the late discovery of Graham's and Enderby's Lands (between lat. 64° and 68° S.), both of which Captain Biscoe believes to be of great extent, has strengthened the probability of Cook's conjecture. These newly observed countries, although placed in latitudes in which herds of wild herbivorous

* Mr. Gardner informs me that the surface of Europe contains about 2,793,000 square geographical miles, the unexplored antarctic region about 7,620,000.

animals are met with in the northern hemisphere, nay, where man himself exists, and where there are ports and villages, are described as most wintery in their aspect, almost entirely covered, even in summer, with ice and snow, and nearly destitute of animal life.

The distance to which icebergs float from the polar regions on the opposite sides of the line is, as might have been anticipated, very different. Their extreme limit in the northern hemisphere is lat. 40°, as before mentioned, off the eastern coast of Greenland; to which point, as also to the Azores, lat. 42° N., they are sometimes drifted from Baffin's Bay. But in the other hemisphere they have been seen, within the last few years, at different points off the Cape of Good Hope, between latitude 36° and 39°.* One of these was two miles in circumference, and 150 feet high.† Others rose from 250 to 300 feet above the level of the sea, and were therefore of great volume below; since it is ascertained, by experiments on the buoyancy of ice floating in sea-water, that for every solid foot seen above, there must at least be eight feet below water.‡ If ice islands from the north polar regions floated as far, they might reach Cape St. Vincent, and there, being drawn by the current that always sets in from the Atlantic through the Straits of Gibraltar, be drifted into the Mediterranean, so that the serene sky of that delightful region might soon be deformed by clouds and mists.

Before the amount of difference between the temperature of the two hemispheres was ascertained, it

* On Icebergs in low Latitudes, by Captain Horsburgh; read to the Royal Society, February, 1830.

† Edin. New Phil. Journ. No. xv. p. 193.; January, 1830.

‡ Scoresby's Arctic Regions, vol. i. p. 234.

was referred by many astronomers to the acceleration of the earth's motion in its perihelium; in consequence of which the spring and summer of the southern hemisphere are shorter, by nearly eight days, than those seasons north of the equator. But Sir J. Herschel reminds us that the excess of eight days in the duration of the sun's presence in the northern hemisphere is not productive of an excess of annual light and heat; since, according to the laws of elliptic motion, it is demonstrable that whatever be the ellipticity of the earth's orbit, the two hemispheres must receive *equal absolute quantities* of light and heat per annum, the proximity of the sun in perigee exactly compensating the effect of its swifter motion.* Humboldt, however, observes, that the accumulation of heat in the southern hemisphere must be less on account of the greater emission of radiant heat, which continues during a winter longer by eight days than that on the other side of the equator.†

Perhaps no very sensible effect may be produced by this source of disturbance, yet the geologist should bear in mind that to a certain extent it operates alternately on each of the two hemispheres for a period of upwards of 10,000 years, dividing unequally the times during which the annual supply of solar light and heat is received. This cause may sometimes tend to counter-

* This follows, observes Herschel, from a very simple theorem, which may be thus stated: — "The amount of heat received by the earth from the sun, while describing any part of its orbit, is proportional to the angle described round the sun's centre." So that if the orbit be divided into two portions by a line drawn *in any direction* through the sun's centre, the heat received in describing the two unequal segments of the ellipse so produced will be equal. Geol. Trans. vol. iii. part ii. p. 298.; second series.

† On Isothermal Lines.

balance inequalities of temperature resulting from other far more influential circumstances; but, on the other hand, it must sometimes tend to increase the extreme of deviation arising from certain combinations of causes.

But whatever may be at present the inferiority of heat in the temperate and frigid zones south of the line, it is quite evident that the cold would be far more intense if there happened, instead of open sea, to be tracts of elevated land between the 55th and 70th parallel; and on the other hand, the cold would be moderated if there was more land between the line and the forty-fifth degree of south latitude.

Changes in the position of land and sea may give rise to vicissitudes in climate. — Having offered these brief remarks on the diffusion of heat over the globe in the present state of the surface, I shall now proceed to speculate on the vicissitudes of climate, which must attend those endless variations in the geographical features of our planet which are contemplated in geology. That our speculations may be confined within the strict limits of analogy, I shall assume, 1st, That the proportion of dry land to sea continues always the same. 2dly, That the volume of the land rising above the level of the sea is a constant quantity; and not only that its mean, but that its extreme height, are liable only to trifling variations. 3dly, That both the mean and extreme depth of the sea are invariable; and, 4thly, It may be consistent with due caution to assume that the grouping together of the land in great continents is a necessary part of the economy of nature; for it is possible that the laws which govern the subterranean forces, and which act simultaneously along certain lines, cannot but produce, at every epoch, continuous mountain-chains; so that the subdivision

of the whole land into innumerable islands may be precluded.

If it be objected, that the maximum of elevation of land and depth of sea are probably not constant, nor the gathering together of all the land in certain parts, nor even perhaps the relative extent of land and water, I reply, that the arguments about to be adduced will be strengthened, if, in these peculiarities of the surface, there be considerable deviations from the present type. If, for example, all other circumstances being the same, the land is at one time more divided into islands than at another, a greater uniformity of climate might be produced, the mean temperature remaining unaltered: or if, at another era, there were mountains higher than the Himalaya, these, when placed in high latitudes, would cause a greater excess of cold. Or, if we suppose that at certain periods no chain of hills in the world rose beyond the height of 10,000 feet, a greater heat might then have prevailed than is compatible with the existence of mountains thrice that elevation.

However constant may be the relative proportion of sea and land, we know that there is annually some small variation in their respective geographical positions, and that in every century the land is in some parts raised, and in others depressed by earthquakes; and so likewise is the bed of the sea. By these and other ceaseless changes, the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth, after it had once become the habitation of living crea-

tures; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant if we consider how slightly the highest mountain-chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet in diameter, by a grain of sand less than one-twentieth of an inch in thickness.*

The superficial inequalities of the earth, then, may be deemed minute in quantity, and their distribution at any particular epoch must be regarded in geology as temporary peculiarities, like the height and outline of the cone of Vesuvius in the interval between two eruptions. But although, in reference to the magnitude of the globe, the unevenness of the surface is so unimportant, it is on the position and direction of these small inequalities that the state of the atmosphere, and both the local and general climate, are mainly dependent.

Before considering the effect which a material change in the distribution of land and sea must occasion, it may be well to remark, how greatly organic life may be affected by those minor variations, which need not in the least degree alter the general temperature. Thus, for example, if we suppose, by a series of convulsions, a certain part of Greenland to become sea, and, in compensation, a tract of land to rise and connect Spitzbergen with Lapland, — an accession not greater in amount than one which the geologist can prove to have occurred in certain districts bordering the Mediterranean, within a comparatively modern period, — this altered form of the

* Malte-Brun's System of Geography, book i. p. 6.

land might cause an interchange between the climate of certain parts of North America and of Europe, which lie in corresponding latitudes. Many European species of plants and animals would probably perish in consequence, because the mean temperature would be greatly lowered; and others would fail in America, because it would there be raised. On the other hand, in places where the mean annual heat remained unaltered, some species which flourish in Europe, where the seasons are more uniform, would be unable to resist the greater heat of the North American summer, or the intenser cold of the winter; while others, now fitted by their habits for the great contrast of the American seasons, would not be fitted for the *insular* climate of Europe. The vine, for example, according to Humboldt, can be cultivated with advantage 10° farther north in Europe than in North America. Many plants endure severe frost, but cannot ripen their seeds without a certain intensity of summer heat and a certain quantity of light; others cannot endure a similar intensity either of heat or cold.

It is now established that many of the existing species of animals have survived great changes in the physical geography of the globe. If such species be termed modern, in comparison to races which preceded them, their remains, nevertheless, enter into submarine deposits many hundred miles in length, and which have since been raised from the deep to no inconsiderable altitude. When, therefore, it is shown that changes in the temperature of the atmosphere may be the consequence of such physical revolutions of the surface, we ought no longer to wonder that we find the distribution of existing species to be *local*, in regard to *longitude* as well as latitude. If all species

were now, by an exertion of creative power, to be diffused uniformly throughout those zones where there is an equal degree of heat, and in all respects a similarity of climate, they would begin from this moment to depart more and more from their original distribution. Aquatic and terrestrial species would be displaced, as Hooke long ago observed, so often as land and water exchanged places; and there would also, by the formation of new mountains and other changes, be transpositions of climate, contributing, in the manner before alluded to, to the local extermination of species.*

If we now proceed to consider the circumstances required for a *general* change of temperature, it will appear, from the facts and principles already laid down, that whenever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there is more sea between or near the tropics; while, on the contrary, so often as the above conditions are reversed, the heat will be greater. (See Map, Pl. I.) If this be admitted, it will follow, that unless the superficial inequalities of the earth be fixed and permanent, there must be never-ending fluctuations in the mean temperature of every zone; and that the climate of one era can no more be a type of every other, than is one of our four seasons of all the rest.

It has been well said, that the earth is covered by an ocean, in the midst of which are two great islands, and many smaller ones; for the whole of the continents and islands occupy an area scarcely exceeding one fourth of the whole superficies of the spheroid.

* A full consideration of the effect of changes in physical geography on the distribution and extinction of species, is given in book iii.

Now, on a fair estimate of probability, we may reasonably assume that there will not, at any given epoch, be more than about one fourth dry land in a particular region; such, for example, as within the arctic and antarctic circles. If, therefore, at present there should happen, in the only one of these regions which we can explore, to be much *more* than this average proportion of land, and some of it above five thousand feet in height, this alone affords ground for concluding that, in the present state of things, the mean heat of the climate is below that which the earth's surface, in its more ordinary state, would enjoy. This presumption would be heightened, were we to assume that the mean depth of the Atlantic and Pacific oceans is as great as some astronomers have imagined*; for then

* See Young's Nat. Phil. Lect. xlvii.; Mrs. Somerville's Connex. of Phys. Sci., sect. 14. p. 110. Laplace, endeavouring to estimate the probable depth of the sea from some of the phenomena of the tides, says of the ocean generally, "que sa profondeur moyenne est du même ordre que la hauteur moyenne des continens et des îles au-dessus de son niveau, hauteur qui ne surpasse pas mille mètres (3280 ft.)." Mec. Céleste, Bk. xi. et Syst. du Monde, p. 254. The expression "du même ordre" admits, in mathematical language, of considerable latitude of signification, and does not mean that the depth of the water below the level of the sea corresponds exactly to the height of the land above it. I have endeavoured, in vain, after consulting several eminent mathematicians, among others, Professor Airy, Mr. Lubbock, and Mr. Whewell, to arrive at some conclusion as to the absolute depth of the ocean. My informants all agree in declaring that the hypothetical data on which the calculations of Laplace necessarily proceeded, cannot give even an approximation to a solution of the problem. Neither does Mr. Whewell believe in the alleged approach to uniformity in the depth of the ocean, which some have wished to deduce from the supposed smallness of the difference of the two tides occurring on the same day. (London, March, 1835).

we might look not only for more than two thirds sea in the frigid zones, but for water of great depth, which could not readily be reduced to the freezing point. The same opinion is confirmed, when we compare the quantity of land lying between the poles and the 30th parallels of north and south latitude, with the quantity placed between those parallels and the equator; for, it is clear, that we have at present not only more than the usual degree of cold in the polar regions, but also less than the average quantity of heat within the tropics.

Position of land and sea which might produce the extreme of cold of which the earth's surface is susceptible. — To simplify our view of the various changes in climate, which different combinations of geographical circumstances may produce, we shall first consider the conditions necessary for bringing about the extreme of cold, or what may be termed the winter of the "great year," or geological cycle, and afterwards, the conditions requisite to produce the maximum of heat, or the summer of the same year.

To begin with the northern hemisphere. Let us suppose those hills of the Italian peninsula and of Sicily, which are of comparatively modern origin, and contain many fossil shells identical with living species, to subside again into the sea, from which they have been raised, and that an extent of land of equal area and height (varying from one to three thousand feet) should rise up in the Arctic Ocean between Siberia and the north pole. In speaking of such changes, I shall not allude to the manner in which I conceive it possible that they may be brought about, nor of the time required for their accomplishment—reserving for a future occasion, not only the proofs that revolu-

tions of equal magnitude have taken place, but that analogous operations are still in gradual progress. The alteration now supposed in the physical geography of the northern regions would cause additional snow and ice to accumulate where now there is usually an open sea; and the temperature of the greater part of Europe would be somewhat lowered, so as to resemble more nearly that of corresponding latitudes of North America: or, in other words, it might be necessary to travel about 10° farther south in order to meet with the same climate which we now enjoy. No compensation would be derived from the disappearance of land in the Mediterranean countries; but the contrary, since the mean heat of the soil in those latitudes is probably far above that which would belong to the sea, by which we imagine it to be replaced.

But let the configuration of the surface be still further varied, and let some large district within or near the tropics, such as Mexico, with its mountains rising to the height of twelve thousand feet and upwards, be converted into sea, while lands of equal elevation and extent rise up in the arctic circle. From this change there would, in the first place, result a sensible diminution of temperature near the tropic, for the soil of Mexico would no longer be heated by the sun; so that the atmosphere would be less warm, as also the neighbouring Atlantic. On the other hand, the whole of Europe, Northern Asia, and North America, would be chilled by the enormous quantity of ice and snow, thus generated at vast heights on the new arctic continent. If, as we have already seen, there are now some points in the southern hemisphere where snow is perpetual down to the level of the sea, in latitudes as low as central England, such might assuredly be

the case throughout a great part of Europe, under the change of circumstances above supposed; and if at present the extreme range of drifted icebergs is the Azores, they might easily reach the equator after the assumed alteration. But to pursue the subject still farther, let the Himalaya mountains, with the whole of Hindostan, sink down, and their place be occupied by the Indian ocean, while an equal extent of territory and mountains, of the same vast height, rise up between North Greenland and the Orkney islands. It seems difficult to exaggerate the amount to which the climate of the northern hemisphere would then be cooled.

But the refrigeration brought about at the same time in the southern hemisphere, would be nearly equal, and the difference of temperature between the arctic and equatorial latitudes would not be much greater than at present; for no important disturbance can occur in the climate of a particular region, without its immediately affecting all other latitudes, however remote. The heat and cold which surround the globe are in a state of constant and universal flux and reflux. The heated and rarefied air is always rising and flowing from the equator towards the poles in the higher regions of the atmosphere; while in the lower, the colder air is flowing back to restore the equilibrium. That this circulation is constantly going on in the aërial currents is not disputed; it is often proved by the opposite course of the clouds at different heights, and the fact was farther illustrated in a striking manner by an event which happened during the present century. The trade wind continually blows with great force from the island of Barbadoes to that of St. Vincent's; notwithstanding which, during the eruption of

the volcano in the island of St. Vincent, in 1812, ashes fell in profusion from a great height in the atmosphere upon Barbadoes. This apparent transportation of matter against the wind, confirmed the opinion of the existence of a counter-current in the higher regions, which had previously rested on theoretical conclusions only.*

That a corresponding interchange takes place in the seas, is demonstrated, according to Humboldt, by the cold which is found to exist at great depths between the tropics; and, among other proofs, may be mentioned the mass of warmer water which the Gulf stream is constantly bearing northwards, while a cooler current flows *from* the north along the coast of Greenland and Labrador, and helps to restore the equilibrium.†

Currents of heavier and colder water pass from the poles towards the equator, which cool the inferior parts of the ocean‡; so that the heat of the torrid zone and the cold of the polar circle balance each other. The refrigeration, therefore, of the polar regions, resulting from the supposed alteration in the distribution of land and sea, would be immediately communicated to the tropics, and from them its influence would extend to the antarctic circle, where the atmosphere and the ocean would be cooled, so that ice and snow

* Daniell's Meteorological Essays, p. 103.

† In speaking of the circulation of air and water in this chapter, no allusion is made to the trade winds, or to irregularities in the direction of currents, caused by the rotatory motion of the earth. These causes prevent the movements from being direct from north to south, or from south to north, but they do not affect the theory of a constant circulation.

‡ See note, p. 168., on the increasing density of sea-water in proportion to the degree of cold.

would augment. Although the mean temperature of higher latitudes in the southern hemisphere is, as before stated, for the most part lower than that of the same parallels in the northern, yet, for a considerable space on each side of the line, the mean annual heat of the waters is found to be the same in corresponding parallels. If, therefore, by the new position of the land, the formation of icebergs had become of common occurrence in the northern temperate zone, and if these were frequently drifted as far as the equator, the same degree of cold which they generated would immediately be communicated as far as the tropic of Capricorn, and from thence to the lands or ocean to the south.

The freedom, then, of the circulation of heat and cold from pole to pole being duly considered, it will be evident that the mean temperature which may prevail at the same point at two distinct periods, may differ far more widely than that of any two points in the same parallels of latitude, at one and the same period. For the range of temperature, or, in other words, the curvature of the isothermal lines in a given zone, and at a given period, must always be circumscribed within narrow limits, the climate of each place in that zone being controlled by the combined influence of the geographical peculiarities of all other parts of the earth. Whereas, if we compare the state of things at two distinct and somewhat distant epochs, a particular zone may at one time be under the influence of one class of disturbing causes, and at another time may be affected by an opposite combination. The lands, for example, to the north of Greenland cause the present climate of North America to be colder than that of Europe in the same latitudes; but the excess of cold

is not so great as it would have been if the western hemisphere had been entirely isolated, or separated from the eastern like a distinct planet. For not only does the refrigeration produced by Greenland chill to a certain extent the atmosphere of northern and western Europe, but the mild climate of Europe reacts also upon North America, and moderates the chilling influence of the adjoining polar lands.

To return to the state of the earth after the changes above supposed, we must not omit to dwell on the important effects to which a wide expanse of perpetual snow would give rise. It is probable that nearly the whole sea, from the poles to the parallels of 45°, would be frozen over; for it is well known that the immediate proximity of land is not essential to the formation and increase of field ice, provided there be in some part of the same zone a sufficient quantity of glaciers generated on or near the land, to cool down the sea. Captain Scoresby, in his account of the arctic regions, observes, that when the sun's rays "fall upon the snow-clad surface of the ice or land, they are in a great measure reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other."*

Now field ice is almost always covered with snow†; and thus not only land as extensive as our existing continents, but immense tracts of sea in the frigid and temperate zones, might present a solid surface covered with snow, and reflecting the sun's rays for the greater part of the year. Within the tropics, moreover, where

* See Scoresby's Arctic Regions, vol. i. p. 378. † Ib. p. 320.

the ocean now predominates, the sky would no longer be serene and clear, as in the present era; but masses of floating ice would cause quick condensations of vapour, so that fogs and clouds would deprive the vertical rays of the sun of half their power. The whole planet, therefore, would receive annually a smaller proportion of the solar influence, and the external crust would part, by radiation, with some of the heat which had been accumulated in it, during a different state of the surface. This heat would be dissipated in the spaces surrounding our atmosphere, which, according to the calculations of M. Fourier, have a temperature much inferior to that of freezing water.

After the geographical revolution above assumed, the climate of equinoctial lands might be brought at last to resemble that of the present temperate zone, or perhaps be far more wintery. They who should then inhabit such small isles and coral reefs as are now seen in the Indian ocean and South Pacific, would wonder that zoophytes of large dimensions had once been so prolific in their seas; or if, perchance, they found the wood and fruit of the cocoa-nut tree or the palm silicified by the waters of some ancient mineral spring, or incrusted with calcareous matter, they would muse on the revolutions which had annihilated such genera, and replaced them by the oak, the chestnut, and the pine. With equal admiration would they compare the skeletons of their small lizards with the bones of fossil alligators and crocodiles more than twenty feet in length, which, at a former epoch, had multiplied between the tropics: and when they saw a pine included in an iceberg, drifted from latitudes which we now call temperate, they would be astonished at the proof thus afforded, that forests had once grown

where nothing could be seen in their own times but a wilderness of snow.

If the reader hesitate to suppose so extensive an alteration of temperature as the probable consequence of geographical changes, confined to one hemisphere, he should remember how great are the local anomalies in climate now resulting from the peculiar distribution of land and sea in certain regions. Thus, in the island of South Georgia, before mentioned (p. 171.), Captain Cook found the everlasting snows descending to the level of the sea, between lat. 54° and 55° S.; no trees or shrubs were to be seen, and in summer a few rocks only, after a partial melting of the ice and snow, were scantily covered with moss and tufts of grass. If such a climate can now exist at the level of the sea in a latitude corresponding to that of Yorkshire, in spite of all those equalizing causes before enumerated, by which the mixture of the temperatures of distant regions is facilitated throughout the globe, what rigours might we not anticipate in a winter generated by the transfer of the mountains of India to our arctic circle!

But we have still to contemplate the additional refrigeration which might be effected by changes in the relative position of land and sea in the southern hemisphere. If the remaining continents were transferred from the equatorial and contiguous latitudes to the south polar regions, the intensity of cold produced might, perhaps, render the globe uninhabitable. We are too ignorant of the laws governing the direction of subterranean forces, to determine whether such a crisis be within the limits of possibility. At the same time, it may be observed, that no distribution of land can well be imagined more irregular, or, as it were, capri-

MAPS
shewing the position
OF LAND AND SEA
which might produce the extremes of
HEAT AND COLD
in the Climates *of the*
GLOBE

Observations. *These Maps are intended to shew that Continents & Islands having the same shape and relative dimensions as those now existing might be placed so as to occupy either the equatorial or polar regions*

In Fig. N.º 1 scarcely any of the land extends from the Equator towards the poles beyond the 30.th parallel of Latitude and in Fig. 2. a very small proportion of it extends from the poles towards the Equator beyond the 40.th parallel of Latitude

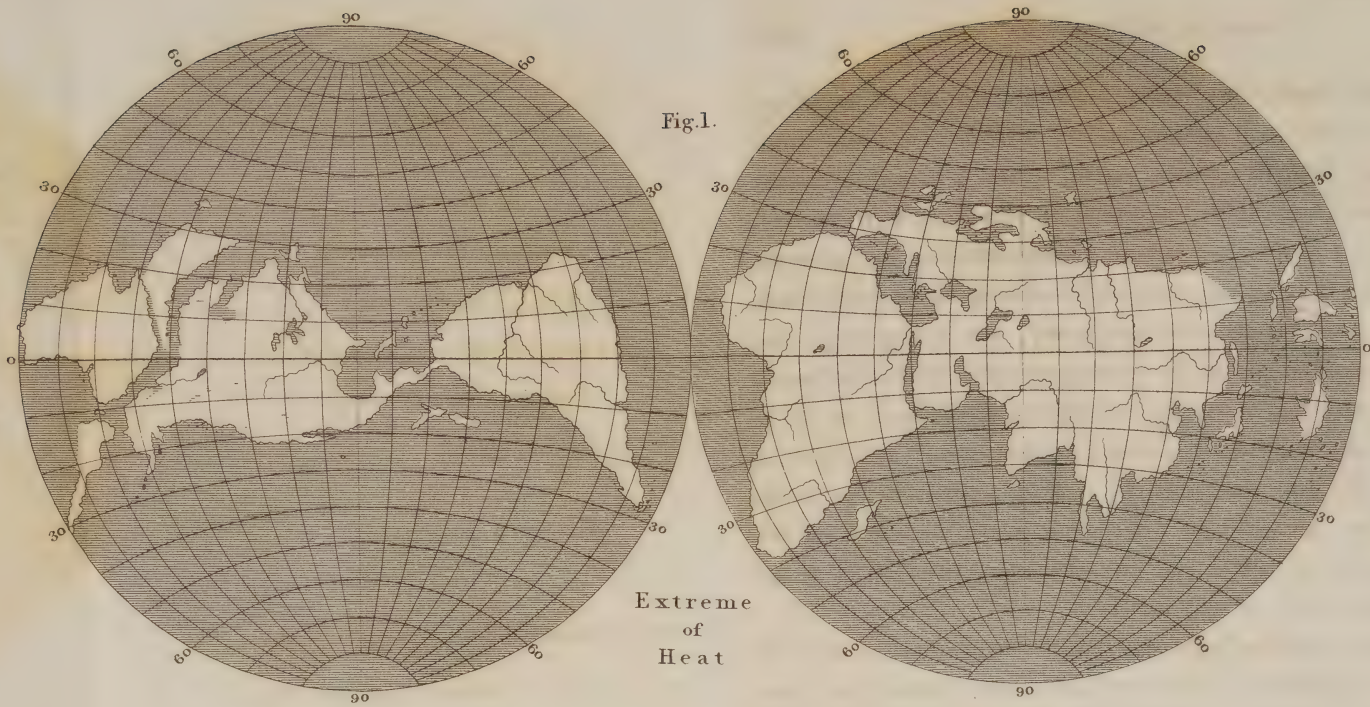


Fig. 1.

Extreme of Heat

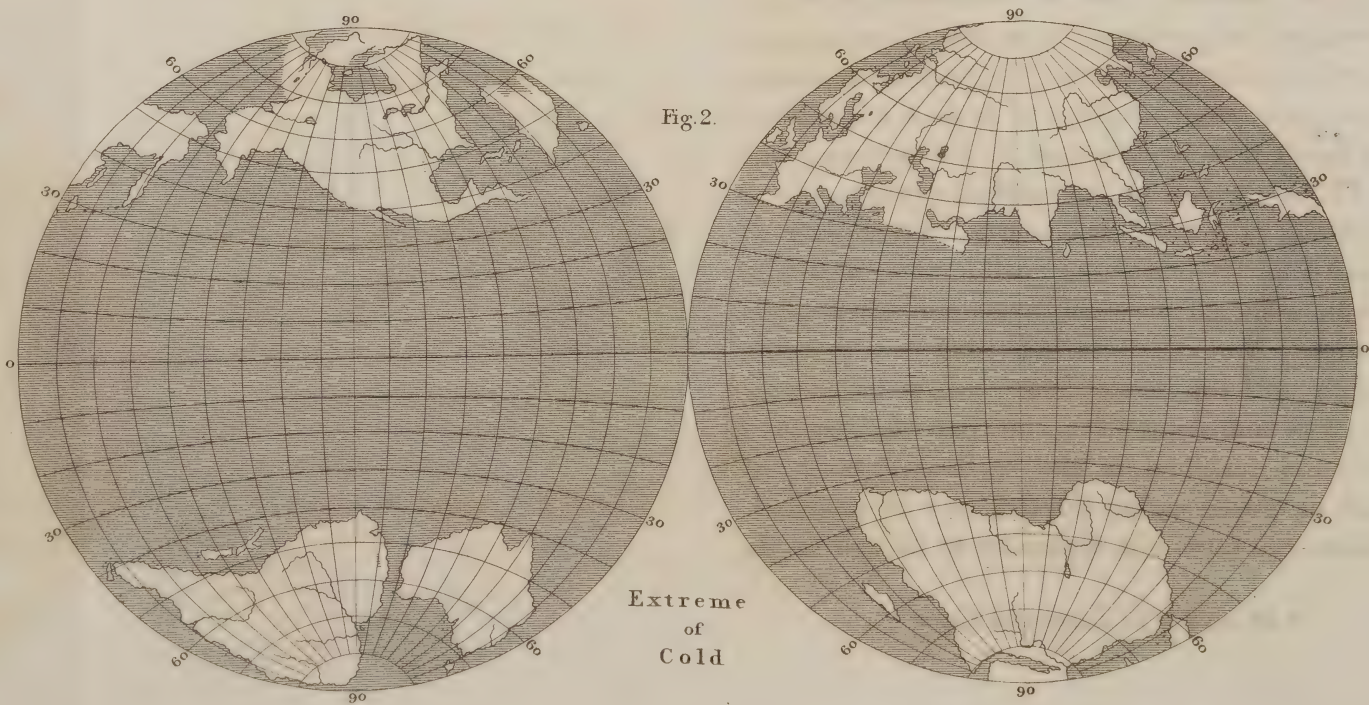


Fig. 2.

Extreme of Cold

cious, than that which now prevails; for at present, by drawing a line in a particular direction, the globe may be divided into two equal parts, in such a manner, that one hemisphere shall be entirely covered with water, with the exception of some promontories and islands, while the other shall contain less water than land; and, what is still more extraordinary, on comparing the extratropical lands in the northern and southern hemispheres, the lands in the northern are found to be to those in the southern in the proportion of thirteen to one!* To imagine all the lands, therefore, in high, and all the sea in low latitudes, as delineated in the annexed plate (Pl. I.), would scarcely be a more anomalous state of the surface.

Position of land and sea which might give rise to the extreme of heat.—Let us now turn from the contemplation of the winter of the "great year," and consider the opposite train of circumstances which would bring on the spring and summer. To imagine all the lands to be collected together in equatorial latitudes, and a few promontories only to project beyond the thirtieth parallel, as represented in the annexed map (fig. 1. Pl. I.), would be undoubtedly to suppose an extreme result of geological change. But if we consider a mere approximation to such a state of things, it would be sufficient to cause a general elevation of temperature. Nor can it be regarded as a visionary idea, that, amidst the revolutions of the earth's surface, the quantity of land should, at certain periods, have been simultaneously lessened in the vicinity of both the poles, and increased within the tropics. We must recollect that even now it is necessary to ascend to the

* Humboldt on Isothermal Lines.

height of fifteen thousand feet in the Andes under the line, and in the Himalaya mountains, which are without the tropic, to seventeen thousand feet, before we reach the limit of perpetual snow. On the northern slope, indeed, of the Himalaya range, where the heat radiated from a great continent moderates the cold, there are meadows and cultivated land at an elevation equal to the height of Mont Blanc.* If then there were no arctic lands to chill the atmosphere, and freeze the sea, and if the loftiest chains were near the line, it seems reasonable to imagine that the highest mountains might be clothed with a rich vegetation to their summits, and that nearly all signs of frost would disappear from the earth.

When the absorption of the solar rays was in no region impeded, even in winter, by a coat of snow, the mean heat of the earth's crust would augment to considerable depths, and springs, which we know to be in general an index of the mean temperature of the climate, would be warmer in all latitudes. The waters of lakes, therefore, and rivers, would be much hotter in winter, and would be never chilled in summer by melted snow and ice. A remarkable uniformity of climate would prevail amid the archipelagos of the temperate and polar oceans, where the tepid waters of equatorial currents would freely circulate. The general humidity of the atmosphere would far exceed that of the present period, for increased heat would promote evaporation in all parts of the globe. The winds would be first heated in their passage over the tropical plains, and would then gather moisture from the surface of the deep, till, charged with vapour,

* Humboldt, Tableaux de la Nature, tom. i. p. 112.

they arrived at extreme northern and southern regions, and there encountering a cooler atmosphere, discharged their burden in warm rain. If, during the long night of a polar winter, the snows should whiten the summit of some arctic islands, they would be dissolved as rapidly by the returning sun, as are the snows of Etna by the blasts of the sirocco.

We learn from those who have studied the geographical distribution of plants, that in very low latitudes, at present, the vegetation of small islands remote from continents has a peculiar character; the ferns and allied families, in particular, bearing a great proportion to the total number of other plants. Other circumstances being the same, the more remote the isles are from the continents, the greater does this proportion become. Thus, in the continent of India, and the tropical parts of New Holland, the proportion of ferns to the phænogamous plants is only as one to twenty-six; whereas, in the South-Sea Islands, it is as one to four, or even as one to three.*

We might expect, therefore, in the summer of the "great year," which we are now considering, that there would be a predominance of tree-ferns and plants allied to palms and arborescent grasses in the islands of the wide ocean, while the dicotyledonous plants and other forms now most common in temperate regions would almost disappear from the earth. Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sciences Nat. Nov. 1828.

the pterodactyle might flit again through umbrageous groves of tree-ferns. Coral reefs might be prolonged once more beyond the arctic circle, where the whale and the narwal now abound; and turtles might again be found in regions now inhabited by the walrus and the seal.

But, not to indulge too far in these speculations, I may observe, in conclusion, that however great, during the lapse of ages, may be the vicissitudes of temperature in every zone, it accords with this theory that the general climate should not experience any sensible change in the course of a few thousand years; because that period is insufficient to affect the leading features of the physical geography of the globe. Notwithstanding the apparent uncertainty of the seasons, it is found that the mean temperature of particular localities is very constant, when observations made for a sufficient series of years are compared.

Yet, there must be exceptions to this rule, and even the labours of man have, by the drainage of lakes and marshes, and the felling of extensive forests, caused such changes in the atmosphere as greatly to raise our conception of the more important influence of those forces to which, in certain latitudes, even the existence of land or water, hill or valley, lake or sea, must be ascribed. If we possessed accurate information of the amount of *local* fluctuation in climate in the course of twenty centuries, it would often, undoubtedly, be considerable. Certain tracts, for example, on the coast of Holland and of England consisted of cultivated land in the time of the Romans, which the sea, by gradual encroachments, has at length occupied. Here, at least, a slight alteration has been effected; for neither the distribution of heat in the different seasons, nor the

mean annual temperature of the atmosphere investing the sea, is precisely the same as that which rests upon the land.

In those countries, also, where earthquakes and volcanos are in full activity, a much shorter period may produce a sensible variation. The climate of the once fertile plain of Malpais in Mexico must differ materially from that which prevailed before the middle of the last century; for, since that time, six mountains, the highest of them rising sixteen hundred feet above the plateau, have been thrown up by volcanic eruptions. It is by the repetition of an indefinite number of such local revolutions, and by slow movements extending simultaneously over wider areas, as will be afterwards shewn, that a general change of climate may finally be brought about.

CHAPTER VIII.

FARTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Whether the geographical features of the northern hemisphere, at the period of the deposition of the oldest fossiliferous strata, were such as might have given rise to an extremely hot climate — State of the surface when the greywacké, or transition formations, originated — State of the same when the mountain limestone, coal-sandstones, and coal were deposited (p. 199.) — Changes in physical geography, between the carboniferous period and the chalk — Abrupt transition from the secondary to the tertiary fossils (p. 202.) — Accession of land, and elevation of mountain chains, after the consolidation of the secondary rocks — Explanation of Map, shewing the area covered by sea, since the commencement of the tertiary period (p. 209.) — Remarks on the theory of the diminution of central heat (p. 216.) — Astronomical causes of fluctuations in climate (p. 219.).

Whether the geographical features of the northern hemisphere, at the period of the deposition of the oldest fossiliferous strata, were such as might have given rise to an extremely hot climate.—In the sixth chapter, I stated the arguments derived from organic remains for concluding that the mean annual temperature of the northern hemisphere was considerably more elevated when the ancient carboniferous strata were deposited than it is at present; as also that the climate

had been modified more than once since that epoch, and that it had been reduced by successive changes more and more nearly to that now prevailing in the same latitudes. Farther, I endeavoured, in the last chapter, to prove that vicissitudes in climate of no less importance may be expected to recur in future, if it be admitted that causes now active in nature have power, in the lapse of ages, to produce considerable variations in the relative position of land and sea. It remains to inquire whether the alterations, which the geologist can prove to have *actually taken place* at former periods, in the geographical features of the northern hemisphere, coincide in their nature, and in the time of their occurrence, with such revolutions in climate as would naturally have resulted, according to the meteorological principles already explained.

The oldest system of rocks which afford by their organic remains any decisive evidence as to climate, or the former position of land and sea, are those generally known as the *transition*, or *greywacké*, formations. These have been found in England, France, Germany, Sweden, Russia, and other parts of central and northern Europe, as also in the great Lake district of Canada and the United States; and they appear to have been deposited in a sea of considerable extent. The fossils have been regarded by many naturalists as indicating a greater uniformity in the species of marine animals inhabiting the sea at that early period than would now be found to prevail in a similar extent of ocean. The number and magnitude of the multilocular or chambered univalves, and of the corals, obtained from the limestones of this group, recall the forms now most largely developed in tropical seas. Hitherto few vegetable remains have been noticed, but such as are

mentioned are said to agree more nearly with the plants of the carboniferous era than any other, and would therefore imply a tropical and humid atmosphere.*

Carboniferous group.—This group comes next in the order of succession, and one of its principal members, the mountain limestone, was evidently a marine formation, as is shewn by the shells and corals which it contains. That the ocean of that period was of considerable extent in our latitudes, we may infer from the continuity of these calcareous strata over large areas. The same group appears also to have been traced not only through different parts of Europe, but also in North America, towards the borders of the arctic sea.†

The coal itself is admitted to be of vegetable origin,

* Mr. Murchison, during his investigations of the English and Welsh transition rocks, has not met with any vegetable remains of land plants; but MM. Elie de Beaumont, Virlet, and De la Beche have pointed out places where they occur in members of that series. Mr. Weaver also formerly supposed that the coal and coal-plants of Munster, in Ireland, belonged to the transition rocks; but he has lately retracted this opinion, and believes that the coal and plants alluded to occur in the carboniferous series.

† It appears from the observations of Dr. Richardson, made during the expedition under the command of Captain Franklin to the north-west coast of America, and from the specimens presented by him to the Geological Society of London, that, between the parallels of 60° and 70° north latitude, there is a great calcareous formation, stretching towards the mouth of the Mackenzie river, in which are included corallines, productæ, terebratulæ, &c. having a close affinity in generic character to those of our mountain limestone, of which the group has been considered the equivalent. There is also in the same region a newer series of strata, in which are shales with impressions of ferns, lepidodendrons, and other vegetables, and also ammonites. — *Proceedings of Geol. Soc.* No. 7, p. 68 *March* 1828.

and the state of the plants, and the beautiful preservation of their leaves in the accompanying shales, precludes the idea of their having been floated from great distances. As the species were evidently terrestrial, we must suppose that some dry land was not far distant; and this opinion is confirmed by the shells found in some strata of the Newcastle and Shropshire coal-fields.* These shells, which are chiefly found in the upper coal-measures, are referrible to freshwater genera, and lived, perhaps, in lakes or small estuaries. There are some regions in the northern parts of England and Scotland where the marine mountain limestone alternates with strata containing coal. Such an arrangement of the beds may possibly have been produced by the alternate rising and sinking of large tracts, which were first laid dry, and then submerged again. The land of that period appears to have consisted in part of granitic rocks, the waste of which may have produced the coarse sandstones, such, for example, as the millstone-grit. Volcanic rocks, however, were not wanting, as in Scotland, for example, in the present basins of the Forth and Tay, where they seem to have been poured out on the bottom of the sea during the accumulation of the carboniferous strata.

The arrangement of the sandstones and shales in this group has been thought by some geologists, as by MM. Sternberg, Boué, and Adolphe Brongniart, to favour the hypothesis of the strata having resulted from the waste of small islands placed in rows, and forming the highest points of submarine mountain chains. The disintegration of such clusters of islands

* See Mr. W. Hutton, Foss. Flora of Great Brit. Preface, and Mr. Murchison's papers on Shropshire, &c.

might produce around and between them detached deposits, which, when subsequently raised above the waters, might resemble the strata formed in a chain of lakes; for the boundary heights of such apparent lake-basins would be formed of the rocks once constituting the islands, and they might still continue, after their elevation, to preserve their relative superiority of height, and to surround the newer strata on several sides.*

This idea is also confirmed by the opinion of many botanists who have studied with care the vegetation of the carboniferous period, and who declare that it possesses the character of an insular flora, such as might be looked for in islands scattered through a wide ocean in a tropical and humid climate.

There is, as yet, no well-authenticated instance of the remains of a saurian animal having been found in a member of the carboniferous series.† Now the larger oviparous reptiles usually inhabit rivers of considerable size in warm latitudes; and had crocodiles and other animals of that class been abundant in a fossil state, as in some of the newer secondary formations, we must have inferred the existence of rivers, which could only have drained large tracts of land. Nor have the bones of any terrestrial mammalia rewarded our investigations. Their absence may be regarded by some geologists as corroborating the theory of the non-existence of the higher orders of animals in the earlier ages: but the circumstance may, perhaps, be connected with the

* See some ingenious speculations to this effect, in the work of M. Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c., Ann. des Sci. Nat., Nov. 1828.

† The supposed saurian teeth found by Dr. Hibbert in the carboniferous limestone of Burdie House, near Edinburgh, have since been clearly referred by Dr. Agassiz to sauroidal fish.

geographical condition of the northern hemisphere at that time; for it is a general character of small islands remote from continents, to be altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by man. Kerguelen's land, which is of no inconsiderable size, placed in lat. 49° 20′ S., a parallel corresponding to that of the Scilly islands, may be cited as an example, as may all the groups of fertile islands in the Pacific Ocean between the tropics, where no quadrupeds have been found, except the dog, the hog, and the rat, which have probably been brought to them by the natives, and also bats, which may have made their way along the chain of islands extending from the shores of New Guinea far into the southern Pacific.* Even the islands of New Zealand, which may be compared to Ireland and Scotland in dimensions, appear to possess no indigenous quadrupeds, except the bat; and this becomes the more striking, when we recollect that the northern extremity of New Zealand stretches to latitude 34°, where the warmth of the climate must greatly favour the prolific development of organic life.

So far then the examination of the phenomena exhibited by the greywacké and carboniferous groups accord well with the prevalence of such a state of physical geography in the northern hemisphere as would have given rise to a hot and uniform climate. The subaqueous aspect of the igneous products, — the continuity of marine deposits over vast spaces — the basin-shaped disposition of the fragmentary rocks — the insular character of the flora — the absence of large fluviatile reptiles and of land quadrupeds, — all concur

* Prichard's Phys. Hist. of Man., vol. i. p. 75.

to establish the fact of the northern hemisphere having been pervaded by a great ocean, interspersed, like the south Pacific, with small islets or lands of moderate dimensions, and with insular or submarine volcanos.

Changes in physical geography between the formation of the carboniferous strata and the chalk. — We have evidence in England that the strata of the ancient carboniferous group, already adverted to, were, in many instances, fractured and contorted, and often thrown into a vertical position before the deposition of some of the newer secondary rocks, such as the new red sandstone.

Fragments of the older formations are sometimes included in the conglomerates of the more modern; and some of these fragments still retain their fossil shells and corals, so as to enable us to determine the parent rocks from whence they were derived.* There are other proofs of the disturbance at successive epochs of different secondary rocks before the deposition of others; and satisfactory evidence that, during these reiterated convulsions, the geographical features of the northern hemisphere were frequently modified, and that from time to time new lands emerged from the deep. The vegetation during some parts of the period

* Thus, for example, on the banks of the Avon, in the Bristol coal-field, the dolomitic conglomerate, a rock of an age intermediate between the carboniferous series and the lias, rests on the truncated edges of the coal and mountain limestone, and contains rolled and angular fragments of that limestone, in which its characteristic mountain-limestone fossils are seen. For accurate sections illustrating the disturbances which rocks of the carboniferous series underwent before the newer red sandstone was formed, the reader should consult the admirable memoir of the south-western coal district of England, by Dr. Buckland and Mr. Conybeare, Geol. Trans. vol. i. second series.

in question (from the lias to the chalk inclusive), appears to have approached to that of the larger islands of the equatorial zone; such, for example, as we now find in the West Indian archipelago.* These islands appear to have been drained by rivers of considerable size, which were inhabited by crocodiles and gigantic oviparous reptiles, both herbivorous and carnivorous, belonging for the most part to extinct genera. Of the contemporary inhabitants of the land we have as yet acquired but scanty information, but we know that there were flying reptiles, insects, and small mammifera, allied to the opossum.

When describing the Wealden, one of the upper members of the great secondary series, and evidently of freshwater origin, I shall point out the reasons which incline me to believe that, when those strata originated, a large continent advanced very near to the space now occupied by the south-eastern extremity of England. A river, equal, perhaps, in size to the Ganges or the Indus, seems to have continued to pour its turbid waters for ages into the sea in those latitudes at the period referred to. †

It might at first appear, that the position of a continent so far to the north, as the counties of Surrey and Sussex, at a time when the mean temperature of the climate is supposed to have been much hotter than at present, is inconsistent with the theory before explained, that the heat was caused by the gathering together of all the great masses of land in low latitudes, while the polar regions were almost entirely sea. But provided that none of the land was arctic or

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sci. Nat., Nov. 1828

† See Book iv. chap. xxiii.

antarctic, and a large part of the continents intratropical, considerable elevation of temperature may be presumed to result, even when large continental tracts were prolonged from the equatorial to the temperate zone.

Changes during the tertiary periods. — It will be seen hereafter* that the Maestricht beds are classed as the newest of the secondary series; and the fossils of that group, including the remains of gigantic reptiles, indicate the prevalence of a very hot climate. Between this uppermost member of the secondary series, and the oldest of the newer class of formations called tertiary, there is a remarkable discordance as to *species* of organic remains, none having yet been found common to both. This abrupt transition from one set of fossils to another, is also accompanied by evident signs of a change of climate; the older tertiary species having a far less tropical aspect than those found fossil in the newest secondary group.

Nor are there wanting signs of a decided coincidence between this alteration of climate, and geographical changes which occurred between the formation of the cretaceous series and that of the older tertiary group.† On comparing the tertiary formations of different ages, we may trace a gradual approximation in the imbedded fossils from an assemblage in which extinct species predominate, to one where the species agree for the most part with those now existing. In other words, we find a gradual increase of animals and plants fitted for our present climates, in proportion as the strata which we examine are more modern. Now,

* See Book iv. chap. xxiii.

† See chaps. xxi. and xxii. B. iv. on the period of the elevation of the chalk of the S. E. of England.

during all these successive tertiary periods, there are signs of a great increase of land in European latitudes. By reference to the map (Pl. II.), and its description, p. 209., the reader will see how great have been the physical revolutions which have occurred since the commencement of the tertiary period.

In the present state of Europe, the chalk and associated strata, are of considerable extent, and sometimes rise to the summits of lofty mountains. As all the members of this group contain almost exclusively marine remains, it follows that every tract which they now occupy has, since their origin, been converted from sea into land, and, in some cases, from deep sea to mountains of great altitude. We cannot doubt that part of the changes alluded to happened before the older tertiary strata originated; because these last consist, in a great degree, of the ruins of the newer secondary rocks; which must therefore have been raised and exposed to aqueous erosion before the derivative beds were formed. It will moreover be seen, in the fourth book, (chap. iii.,) that the secondary and tertiary formations, considered generally, may be contrasted as having very different characters; the one appearing to have been deposited in open seas, the other in regions where dry land, lakes, bays, and perhaps inland seas, abounded. The secondary series is almost exclusively marine; the tertiary, even the oldest part, contains lacustrine strata, and not unfrequently freshwater and marine beds alternating.

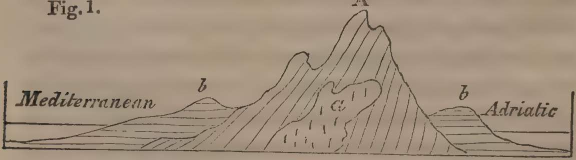
Now, the facts depicted in the map (Pl. II. p. 209.), demonstrate that about two thirds of the present European lands have emerged since the earliest of these tertiary groups originated. Nor is this the only

change which the same region has undergone within this comparatively modern period; some tracts, which were previously land, having gained in altitude, or, on the contrary, having sunk below their former level, within the period alluded to.

The evidence that this rise of land did not take place all at the same time, is most striking. Several Italian geologists, even before the time of Brocchi, had justly inferred that the Apennines were elevated several thousand feet above the level of the Mediterranean, before the deposition of the recent Subapennine beds which flank them on either side. What now constitutes the central calcareous chain of the Apennines must for a long time have been a narrow ridgy peninsula, branching off, at its northern extremity, from the Alps near Savona. This peninsula has since been raised from one to two thousand feet, by which movement the ancient shores, and, for a certain extent, the bed of the contiguous sea, have been laid dry, both on the side of the Mediterranean and the Adriatic.

The nature of these vicissitudes will be explained by the accompanying diagram, which represents a

Fig. 1.



transverse section across the Italian peninsula. The inclined strata A are the disturbed formations of the Apennines into which the ancient igneous rocks *a* are supposed to have intruded themselves. At a lower

level on each flank of the chain are the more recent shelly beds *b b*, which often contain rounded pebbles derived from the waste of contiguous parts of the older Apennine limestone. These, it will be seen, are horizontal, and lie in what is termed "unconformable stratification" on the more ancient series. They now constitute a line of hills of moderate elevation between the sea and the Apennines, but never penetrate to the higher and more ancient valleys of that chain.

The same phenomena are exhibited in the Alps on a much grander scale; those mountains being composed in some even of their higher regions of newer secondary formations, while they are encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria, and at their eastern termination towards Styria and Hungary.* This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand feet deep, and wherein masses of strata accumulated, some single groups of which seem scarcely inferior in thickness to the whole of our secondary formations in England. These marine tertiary strata have been raised to the height of from two to four thousand feet, and consist of formations of different ages, characterized by different assemblages of organized fossils. The older tertiary groups generally rise to the greatest heights, and form interior zones nearest to the central

* See a Memoir on the Alps, by Professor Sedgwick and Mr. Murchison. Trans. of Geol. Soc. second ser. vol. iii. accompanied by a map.

ridges of the Alps. Although we have not yet ascertained the number of different periods at which the Alps gained accessions to their height and width, yet we can affirm, that the last series of movements occurred when the seas were inhabited by many existing species of animals.

We may imagine some future series of convulsions once more to heave up this stupendous chain, together with the adjoining bed of the sea, so that the mountains of Europe may rival the Andes in elevation; in which case the deltas of the Po, Adige, and Brenta, now encroaching upon the Adriatic, might be uplifted so as to form another exterior belt of considerable height around the south-eastern flank of the Alps.

The Pyrenees, also, have acquired the whole of their present altitude, which in Mont Perdu exceeds eleven thousand feet, since the origin of some of the newer members of our secondary series. The granitic axis of that chain only attains about the same height as a ridge formed by marine calcareous beds, the organic remains of which shew them to be the equivalents of our chalk and green-sand series.* The tertiary strata at the base of the chain are raised to the height of only a few hundred feet above the sea, and retain a horizontal position, without partaking in general in the disturbances to which the older series has been subjected; so that the great barrier between France and Spain was almost entirely upheaved in the interval between the deposition of the chalk and certain tertiary strata. The Jura, also, owes a great part of its present elevation to subterranean convulsions which

* This observation, first made by M. Boué, has been since confirmed by M. Dufrénoy.

happened after the deposition of certain tertiary groups.*

The remarkable break above alluded to, between the most modern of the known secondary rocks and the oldest tertiary, may be in some measure apparent only, and ascribable to the present deficiency of our information†; in which case the signs of the intermediate steps, by which a passage was effected from one state of things to another, may hereafter be discovered. Nevertheless, it is far from impossible that the interval between the chalk and tertiary formations constituted an era in the earth's history, when the transition from one class of organic beings to another was, comparatively speaking, rapid. For if the doctrines above explained in regard to vicissitudes of temperature are sound, it will follow that changes of equal magnitude in the geographical features of the globe, may at different periods produce very unequal effects on climate; and, so far as the existence of certain animals and plants depends on climate, the duration of species would be shortened or protracted, according to the rate at which the change of temperature proceeded.

Even if we assume that the intensity of the subterranean disturbing forces is uniform and capable of producing nearly equal amounts of alteration on the surface of the planet, during equal periods of time, still the rate of alteration in climate would be by no means uniform. Let us imagine the quantity of land between the equator and the tropic in one hemisphere to be to that in the other as thirteen to one, which, as

* M. Elie de Beaumont. Ann. des Sci. Nat., Dec. 1829, p. 346.

† See Book iv. chap. 23.

before stated, represents the unequal proportion of the extra-tropical lands in the two hemispheres at present. Then let the first geographical change consist in the shifting of this preponderance of land from one side of the line to the other, from the southern hemisphere, for example, to the northern. Now this need not affect the *general* temperature of the earth. But if, at another epoch, we suppose a continuance of the same agency to transfer an equal volume of land from the torrid zone to the temperate and arctic regions of the northern and southern hemisphere, or into one of them, there might be so great a refrigeration of the mean temperature *in all latitudes*, that scarcely any of the pre-existing races of animals would survive, and, unless it pleased the Author of Nature that the planet should be uninhabited, new species would then be substituted in the room of the extinct. We ought not, therefore, to infer, that equal periods of time are always attended by an equal amount of change in organic life, since a great fluctuation in the mean temperature of the earth, the most influential cause which can be conceived in exterminating whole races of animals and plants, must, in different epochs, require unequal portions of time for its completion.

Engraved by J. Gardner.

Map showing the extent of surface in Europe which has been covered by water since the commencement of the deposition of the older or Eocene Tertiary strata. (Strata of the Paris and London Basins, &c.) *

This map will enable the reader to perceive at a glance the great extent of change in the physical geography of Europe, which can be proved to have taken place since some of the older tertiary strata began to be deposited. The proofs of submergence, during some part or other of this period, in all the districts distinguished by ruled lines, are of a most unequivocal character; for the area thus described is now covered by deposits containing the fossil remains of animals which could only have lived under water. The most ancient part of the period referred to cannot be deemed very remote, considered geologically; because the deposits of the Paris and London basins, of Auvergne, and many other districts belonging to the older tertiary epoch, are newer than the greater part of the sedimentary rocks, commonly called secondary and transition, of which the crust of the globe is composed. The species, moreover, of marine and fresh water testacea, of which the remains are found in these older tertiary formations, are not entirely distinct from such as now live; a proportion of more than three in a hundred of the fossils having been identified with species now living.† Yet, notwithstanding the

* Constructed chiefly from M. Ami Boué's Geological Map of Europe.

† See Book iv. ch. 5.

comparatively recent epoch to which the retrospect is carried, the variations in the distribution of land and sea depicted on the map form only a part of those which must have taken place during the period under consideration. Some approximation has merely been made to an estimate of the amount of *sea converted into land* in part of Europe best known to geologists; but we cannot determine how much land has become sea during the same period; and there may have been repeated interchanges of land and water in the same places, changes of which no account is taken in the map, and respecting the amount of which little accurate information can ever be obtained.

I have extended the sea in two or three instances beyond the limits of the land now covered by tertiary formations, because other geological data have been obtained for inferring the submergence of these tracts after the deposition of the tertiary strata had begun. Thus I shall explain, in the 4th Book*, my reasons for concluding that part of the chalk of England (the north and south downs, for example, together with the intervening secondary tracts) continued beneath the sea until the Eocene or earliest tertiary beds had begun to accumulate.

It is possible also that a considerable part of Caernarvonshire might with propriety have been represented as sea, if our information respecting the geology of that county had been more complete; for marine shells have been found in sand and gravel at the height of one thousand feet above the level of the sea, on the summit of Moel Tryfane, between Snowdon and the Menai Straits. The species, so far as

* Ch. xxi. and xxii.

they can be recognized by the fragments hitherto collected, are recent, and the formation appears to be newer than the crag.*

The introduction of a small bay where the river Ribble enters into the sea in Lancashire is warranted by a newly discovered deposit of tertiary shells covering an area of about thirty miles square in that region.†

A portion also of the primary district in Brittany is divided into islands, because it has been long known to be covered with patches of marine tertiary strata; and when I examined the disposition of these, in company with my friend, Captain S. E. Cook, R. N., in 1830, I was convinced that the sea must have covered much larger areas than are now occupied by these small and detached deposits.

The former connexion of the White Sea and the Gulf of Finland is proved by the fact that a broad band of tertiary strata extends throughout part of the intervening space. The channel, it is true, is represented as somewhat broader than the tract now occupied by the tertiary formation; because the latter is bordered on the north-west by a part of Finland, which is extremely low, and so thickly interspersed with lakes as to be nearly half covered with fresh water.

Certain portions of the western shores of Norway and Sweden have been left blank, because the discovery by Von Buch, Brongniart, and others, of deposits of recent shells along the coasts of those countries,

* J. Trimmer, Esq. Proceedings Geol. Soc. London, No. 22. 1831.

† See memoir by Mr. Murchison, Proceedings of York Meeting, 1831.

at several places and at various heights above the level of the sea, attest the comparatively recent date of the elevation of part of the gneiss and other primary rocks in that country, although we are unable as yet to determine how far the sea may have extended.

On the other hand, a considerable space of low land along the shores on both sides of the Gulf of Bothnia, in the Baltic, is represented as sea, because the gradual rise of the land and the shoaling of the water on that coast, known to have taken place during the historical era, leave no room for doubt that the boundaries of the gulf must have been greatly contracted within a comparatively modern period. Beds of sand and clay are also found far inland in these parts, containing fossil shells of species now inhabiting the neighbouring seas. A portion of Scania, and other tracts in the south of Sweden, have also been marked with ruled lines, because they are covered with clay, sand, and erratic blocks, which appeared to me, after examining the district, to be tertiary. If the space overspread by such formations were more accurately known, the area represented as land in this part of Europe, would, doubtless, be much more circumscribed.

I was anxious, even in the title of this map, to guard the reader against the supposition that it was intended to represent the state of the physical geography of part of Europe at any *one point of time.* The difficulty, or rather the impossibility, of restoring the geography of the globe as it may have existed at any former period, especially a remote one, consists in this, that we can only point out where part of the sea has been turned into land, and are almost always unable to determine what land may have become sea. All maps, therefore, pretending to represent the geography of remote geo-

logical epochs must be ideal. The map under consideration is not a restoration of a former state of things, at any particular moment of time, but a synoptical view of a certain amount of one kind of change (the conversion of sea into land) known to have been brought about within a given period.

It may be stated that the movements of earthquakes occasion the subsidence as well as the upraising of the surface; and that, by the alternate rising and sinking of particular spaces, at successive periods, a great area may have been entirely covered with marine deposits, although the whole may never have been beneath the waters at one time; nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period. I believe, however, that since the commencement of the tertiary period, the dry land in the northern hemisphere has been continually on the increase, both because it is now greatly in excess beyond the average proportion which land generally bears to water on the globe, and because a comparison of the secondary and tertiary strata affords indications, as I shall endeavour to shew hereafter, of a passage from the condition of an ocean interspersed with islands to that of a large continent.*

But supposing it were possible to represent all the vicissitudes in the distribution of land and sea that have occurred during the tertiary period, and to exhibit not only the actual existence of land where there was once sea, but also the extent of surface now submerged which may once have been land, the map would still fail to express all the important revolutions in physical geography which have taken place within

* See Book iv. chap. iii.

the epoch under consideration. For the oscillations of level, as was before stated, have not merely been such as to lift up the land from below the waters, but in some cases to occasion a rise of several thousand feet above the sea. Thus the Alps have acquired an additional altitude of from 2000 to 4000 feet, and even in some places still more; and the Apennines owe a considerable part of their height (from 1000 to 2000 feet and upwards) to subterranean convulsions which have happened within the tertiary epoch.

On the other hand, some mountain chains may have been lowered during the same series of ages, in an equal degree, and shoals may have been converted into deep abysses.*

Concluding remarks on changes in physical geography.—These observations, it may be said, are confined to Europe, and therefore to a space which constitutes but a small portion of the northern hemisphere; but it appeared from the remarks offered in the preceding chapter, that the great Lowland of Siberia, lying chiefly between the latitudes 55° and 75° N. (an area nearly equal to all Europe) is covered for the most part by marine strata, which, from the account given by Pallas, and other writers, may be considered as of tertiary formation.

Upon a review of all the phenomena above enumerated, there appear grounds for inferring that the eras of the principal alterations in climate, as deduced from fossil remains, were coincident with the periods of the most remarkable changes in the former position

* It may be observed, that the facts and inferences exhibited in this map bear not merely on the theory of climate above proposed, but serve also to illustrate the views explained in the third book respecting the migrations of animals and plants, and the gradual extinction of species.

of sea and land. A wide expanse of ocean interspersed with islands, seems to have pervaded the northern hemisphere at the periods when the transition and carboniferous rocks were formed, and the temperature was then hottest and most uniform. Subsequent modifications in climate accompanied the deposition of the secondary formations, when repeated changes were effected in the physical geography of our northern latitudes. Lastly, the refrigeration became most decided, and the climate most nearly assimilated to that now enjoyed, when the lands in Europe and northern Asia had attained their full extension, and the mountain chains their actual height.

It has been objected to this theory of climate, that there are no geological proofs of the prevalence at any former period of a temperature *lower* than that now enjoyed; whereas, if the causes above assigned were the true ones, it might reasonably have been expected that fossil remains would sometimes indicate colder as well as hotter climates than those now established.* In answer to this objection, I may suggest, that our present climates are probably far more distant from the extreme of possible heat than from its opposite extreme of cold. A glance at the map (Pl. I. fig. 1.) will shew that all the existing lands might be placed in the zone intervening between the 30th parallels of latitude on each side of the equator, and that even then they would by no means fill that space. In no other position would they give rise to so high a temperature. But in the present geographical condition

* Allgemeine Literatur Zeitung, No. cxxxix. July, 1833. Since the last edition was published, I have learnt, that I was misinformed in imputing this criticism to Count Sternberg.

of the earth, the land excluded from this zone, and lying between the poles and the parallels of 30°, is in great excess; so much so that, instead of being to the sea in the proportion of 1 to 3, which is as near as possible the average general ratio throughout the globe, it is as 9 to 23.* Hence it ought not to surprise us if, in our geological retrospect, embracing, perhaps, a small part only of a complete cycle of change in the terrestrial climates we should happen, to discover every where the signs of a higher temperature. The strata hitherto examined may have originated when the quantity of equatorial land was always decreasing, and the land in regions nearer the poles augmenting in height and area, until at length it attained its present excess in high latitudes. There is nothing improbable in supposing that the geographical revolutions immediately preceding our times had this tendency; and in that case the refrigeration must have been constant, although, for reasons before explained, the rate of cooling may not have been uniform.

Theory of Central Heat. — The gradual diminution of the supposed central heat of the globe has been resorted to by many geologists as the principal cause

* In this estimate, the space within the antarctic circle, of which nothing certain is known, is not taken into account: if included, it would probably add to the excess of dry land; for the great accumulation of ice in the antarctic region seems to imply the presence of a certain quantity of terra firma. The number of square miles on the surface of the globe, are 148,522,000, the part occupied by the sea being 110,849,000, and that by land, 37,673,000; so that the land is very nearly to the sea as 1 part in 4. I am informed by Mr. Gardner, that, according to a rough approximation, the land between the 30° N. lat. and the pole occupies a space *about equal to that of the sea*, and the land between the 30° S. lat. and the antarctic circle about $\frac{1}{16}$ of that zone.

of alterations of climate. The matter of our planet is imagined, according to the conjecture of Leibnitz, to have been originally in an intensely heated state, and to have been parting ever since with portions of its heat, at the same time that it has contracted its dimensions. There are, undoubtedly, some grounds for inferring, from recent observation and experiment, that the temperature of the earth increases as we descend from the surface to that slight depth to which man can penetrate; but there are no proofs of a secular decrease of heat accompanied by contraction. On the contrary, La Place has shown, by reference to astronomical observations made in the time of Hipparchus, that in the last two thousand years there has been no sensible contraction of the globe by cooling; for had this been the case, even to an extremely small amount, the day would have been shortened, whereas its length has certainly not diminished during that period by $\frac{1}{300}$ th of a second. Baron Fourier, after making a curious series of experiments on the cooling of incandescent bodies, has endeavoured, by profound mathematical calculations, to prove that the actual distribution of heat in the earth's envelope is precisely that which would have taken place if the globe had been formed in a medium of a very high temperature, and had afterwards been constantly cooled.*

Now this conclusion is appealed to by many as corroborating the theory of secular refrigeration, although the phenomenon might perhaps be ascribed, with equal propriety, to the action of volcanic heat, which we

* See a Memoir on the Temperature of the Terrestrial Globe, and the Planetary Spaces, Ann. de Chimie et Phys. tom. xxvii. p. 136. Oct. 1824.

know has, in former ages, shifted its points of chief development over every part of the earth's crust.

M. Cordier announces, as the result of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth; but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences are not in constant relation either with the latitudes or longitudes of places.* All this is precisely what we should have expected to arise from variations in the intensity of volcanic heat, and from that change of position, which the principal theatres of volcanic action can be proved to have undergone.

But the advocates of the doctrine of central heat contend, that although no contraction can be demonstrated to have taken place within the historical period (the operation being slow and the time of observation limited), yet it is no less certain that heat is annually passing out by radiation from the interior of the globe into the planetary spaces. Fourier even undertook to demonstrate that the quantity of heat thus transmitted into space in the course of every century, through every square metre of the earth's surface, would suffice to melt a column of ice having a square metre for its base, and being three metres (or 9 feet 10 inches) high. On the other hand, it is said, there is no assignable mode in which this heat can be again restored to the earth.

Streams of incandescent lava rise up from unknown depths, flow out upon the surface, and before they

* See M. Cordier's Memoir on the Temperature of the Interior of the Earth, read to the Academy of Sciences, 4th June, 1827. — Edin. New Phil. Journal, No. viii. p. 273.

consolidate emit much light and heat. In what manner does the igneous and luminous matter thus withdrawn from our planet return again from the celestial spaces? or, if lost, does it not imply a continual cooling of the central parts of the earth?

This argument may appear plausible, until we reflect how ignorant we are of the sources of volcanic heat, or indeed of the nature of light and heat in general. It is doubtless true, that light and heat are continually emanating from the earth; but, in the same manner, it may be said that they escape without intermission from the sun, and we know not whether there be any compensating causes which again restore them to that luminary.—"It is a mystery," says Herschel, speaking of the sun, "to conceive how so enormous a conflagration (if such it be) can be kept up. Every discovery in chemical science here leaves us completely at a loss, or rather seems to remove farther the prospect of probable explanation. May not," he adds, "a continual current of electric matter be constantly circulating in the sun's immediate neighbourhood, or traversing the planetary spaces?" &c. &c.*

Astronomical causes of fluctuations in climate. — Sir John Herschel has lately inquired, whether there are any astronomical causes which may offer a possible explanation of the difference between the actual climates of the earth's surface, and those which formerly appear to have prevailed. He has entered upon this subject, he says, "impressed with the magnificence of that view of geological revolutions, which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes, regulated by no laws,

* Treatise on Astronomy, § 337.

and reducible to no fixed principles." Geometers, he adds, have demonstrated the absolute invariability of the mean distance of the earth from the sun; whence it would at first seem to follow, that the mean annual supply of light and heat derived from that luminary would be alike invariable: but a closer consideration of the subject will show, that this would not be a legitimate conclusion; but that, on the contrary, the *mean* amount of solar radiation is dependent on the excentricity of the earth's orbit, and therefore liable to variation.*

Now, the excentricity of the orbit, he continues, is actually diminishing, and has been so for ages beyond the records of history. In consequence, the ellipse is in a state of approach to a circle, and the annual average of solar heat radiated to the earth is actually on the *decrease*. So far this is in accordance with geological evidence, which indicates a general refrigeration of climate; but the question remains, whether the amount of diminution which the excentricity may have ever undergone, can be supposed sufficient to account for any sensible refrigeration. The calculations necessary to determine this point, though practicable, have never yet been made, and would be extremely laborious; for they must embrace all the perturbations which the most influential planets, Venus, Mars, Jupiter, and

* The theorem is thus stated: — "The excentricity of the orbit varying, the total quantity of heat received by the earth from the sun in one revolution is inversely proportional to the minor axis of the orbit. The major axis is invariable, and therefore, of course, the absolute length of the year: hence it follows that the mean annual average of heat will also be in the same inverse ratio of the minor axis." — Geol. Trans. second series, vol. iii. p. 295.

Saturn, would cause in the earth's orbit, and in each other's movements round the sun.

The problem is also very complicated, inasmuch as it depends not merely on the ellipticity of the earth's orbit, but on the assumed temperature of the celestial spaces beyond the earth's atmosphere; a matter still open to discussion, and on which MM. Fourier and Herschel have arrived at very different opinions. But if, says Herschel, we suppose an extreme case, as if the earth's orbit should ever become as excentric as that of the planet Juno, or Pallas, a great change of climate might be conceived to result, the winter and summer temperatures being sometimes mitigated, and at others exaggerated, in the same latitudes.

It is much to be desired that the calculations alluded to were executed, as even, if they should demonstrate, as M. Arago thinks highly probable*, that the mean amount of solar radiation can never be materially affected by irregularities in the earth's motion, it would still be satisfactory to ascertain the point. Such inquiries, however, can never supersede the necessity of investigating the consequences of the varying position of continents, shifted as we know them to have been during successive epochs, from one part of the globe to the other.

*Ann. du Bur. des Long. 1834.

CHAPTER IX.

FARTHER DISCUSSION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Theory of the progressive development of organic life — Evidence in its support inconclusive — Vertebrated animals, and plants of the most perfect organization in strata of very high antiquity (p. 227.) — Differences between the organic remains of successive formations — Remarks on the comparatively modern origin of the human race (p. 239.) — The popular doctrine of successive development not confirmed by the admission that man is of modern origin — Introduction of man, to what extent a change in the system (p. 243.)

Progressive development of organic life. — In the preceding chapters I have considered many of the most popular grounds of opposition to the doctrine, that all former changes of the organic and inorganic creation are referrible to one uninterrupted succession of physical events, governed by the laws of Nature now in operation.

As the principles of our science must always remain unsettled so long as no fixed opinions are entertained on this fundamental question, I shall proceed to examine other objections which have been urged against the assumption of the identity of the ancient and modern causes of change. A late distinguished writer has formally advanced some of the most popular of these objections. "It is impossible," he affirms, "to defend the proposition, that the present order of things

is the ancient and constant order of nature, only modified by existing laws: in those strata which are deepest, and which must, consequently, be supposed to be the earliest deposited, forms even of vegetable life are rare; shells and vegetable remains are found in the next order; the bones of fishes and oviparous reptiles exist in the following class; the remains of birds, with those of the same genera mentioned before, in the next order; those of quadrupeds of extinct species in a still more recent class; and it is only in the loose and slightly consolidated strata of gravel and sand, and which are usually called diluvian formations, that the remains of animals such as now people the globe are found, with others belonging to extinct species. But, in none of these formations, whether called secondary, tertiary, or diluvial, have the remains of man, or any of his works, been discovered; and whoever dwells upon this subject must be convinced, that the present order of things, and the comparatively recent existence of man as the master of the globe, is as certain as the destruction of a former and a different order, and the extinction of a number of living forms which have no types in being. In the oldest secondary strata there are no remains of such animals as now belong to the surface; and in the rocks, which may be regarded as more recently deposited, these remains occur but rarely, and with abundance of extinct species; — there seems, as it were, a gradual approach to the present system of things, and a succession of destructions and creations preparatory to the existence of man."*

* Sir H. Davy, Consolations in Travel, Dialogue III. "The Unknown."

In the above passages, the author deduces two important conclusions from geological data: first, that in the successive groups of strata, from the oldest to the most recent, there is a progressive development of organic life, from the simplest to the most complicated forms;—secondly, that man is of comparatively recent origin. It will be easy to show that the first of these propositions, though very generally received, has but a slender foundation in fact. The second, on the contrary, is indisputable; and it is important, therefore, to consider how far its admission is inconsistent with the doctrine, that the system of the natural world may have been uniform from the beginning, or rather from the era when the oldest rocks hitherto discovered were formed.

First, then, let us consider the geological proofs appealed to in support of the theory of the successive development of animal and vegetable life, and their progressive advancement to a more perfect state. No geologists who are in possession of all the data now established respecting fossil remains, will for a moment contend for the doctrine in all its detail, as laid down by the great chemist to whose opinions we have referred; but naturalists, who are not unacquainted with recent discoveries, continue to defend it in a modified form. They say that, in the first period of the world, (by which they mean the earliest of which we have yet procured any memorials,) the vegetation consisted almost entirely of cryptogamic plants, while the animals which co-existed were almost entirely confined to zoophytes, testacea, and a few fish. Plants of a less simple structure succeeded in the next epoch, when oviparous reptiles began also to abound. Lastly, the

terrestrial flora became most diversified and most perfect when the highest orders of animals, the mammifera and birds, were called into existence.

Now, in the first place, it may observed, that many naturalists are guilty of no small inconsistency in endeavouring to connect the phenomena of the earliest vegetation with a nascent condition of organic life, and at the same time to deduce from the numerical predominance of certain types of form, the greater heat of the ancient climate. The arguments in favour of the latter conclusion are without any force, unless we can assume that the rules followed by the Author of Nature in the creation and distribution of organic beings were the same formerly as now; and that, as certain families of animals and plants are now most abundant, or exclusively confined, to regions where there is a certain temperature, a certain degree of humidity, a certain intensity of light, and other conditions, so also the same phenomena were exhibited at every former era.

If this postulate be denied, and the prevalence of particular families be declared to depend on a certain order of precedence in the introduction of different classes into the earth, and if it be maintained that the standard of organization was raised successively, we must then ascribe the numerical preponderance in the earlier ages of plants of simpler structure, *not to the heat*, but to those different laws which regulate organic life in newly created worlds. If, according to the laws of progressive development, cryptogamic plants always flourish for ages before the dicotyledonous order can be established, then is the small proportion of the latter fully explained; for in this case, whatever may have

been the mildness or severity of the climate, they could not make their appearance.

Before we can infer an elevated temperature in high latitudes, from the presence of arborescent Ferns, Lycopodiaceæ, and plants of other allied families, we must be permitted to assume, that at all times, past, present, and future, a heated and moist atmosphere pervading the northern hemisphere has a tendency to produce in the vegetation a predominance of analogous types of form.

In the ancient strata of the carboniferous era, between 200 and 300 species of plants have been found. In these, say the authors of the "Fossil Flora*," no traces have been as yet discovered of the simplest forms of flowerless vegetation, such as Fungi, Lichens, Hepaticæ, or Mosses; while, on the contrary, there appear in their room Ferns, Lycopodiaceæ, and supposed Equisetaceæ, the most perfectly organized cryptogamic plants. In regard to the remains of monocotyledons of the same strata, they consist of palms and plants analogous to Dracænas, Bananas, and the Arrow Root tribe, which are the most highly developed tribes of that class. Among the dicotyledons of the same period coniferous trees were abundant, while the fossil Stigmariæ, which accompany them, belonged probably to the most perfectly organized plants of that class, being allied to the Cacteæ, or Euphorbiaceæ. "But supposing," continue the same authors, "that it could be demonstrated, that neither Coniferæ nor any other dicotyledonous plants

* Fossil Flora of Great Britain, by John Lindley and William Hutton, Esquires. London, 1832. Preface.

existed in the first geological age of land plants, still the theory of progressive development would be untenable; because it would be necessary to show that monocotyledons are inferior in dignity, or, to use a more intelligible expression, are less perfectly formed than dicotyledons. So far is this from being the case, that if the exact equality of the two classes were not admitted, it would be a question whether monocotyledons are not the more highly organized of the two; whether palms are not of greater dignity than oaks, and cerealia than nettles."

Animal remains in the transition, or greywacké, and carboniferous strata.—By far the largest part of the organic remains found in the earth's crust consist of corals and testacea, the bones of vertebrated animals being comparatively rare. When these occur, they belong much more frequently to fish than to reptiles, and but seldom to terrestrial mammalia. This might, perhaps, have been anticipated as the general result of investigation, since all are now agreed that the greater number of fossiliferous strata were deposited beneath the sea, and that the ocean probably occupied in ancient times, as now, the greater part of the earth's surface. We must not, however, too hastily infer from the absence of fossil bones of mammalia in the older rocks, that the highest class of vertebrated animals did not exist in the remoter ages. There are regions at present, in the Indian and Pacific oceans, co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals, without obtaining one bone of a land quadruped. Suppose our mariners were to report, that on sounding in the Indian Ocean near some coral reefs, and at some distance from the

land, they drew up on hooks attached to their line portions of a leopard, elephant, or tapir, should we not be sceptical as to the accuracy of their statements? and if we had no doubt of their veracity, might we not suspect them to be unskilful naturalists? or, if the fact were unquestioned, should we not be disposed to believe that some vessel had been wrecked on the spot?

The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such a floating body not being devoured by sharks or other predaceous fish, such as were those of which we find the teeth preserved in some of the carboniferous strata. But if the carcass should escape, and should happen to sink where sediment was in the act of accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, included for countless ages in solid rock, is it not contrary to all calculation of chances that we should hit upon the exact spot — that mere point in the bed of an ancient ocean, where the precious relic was entombed? Can we expect for a moment, when we have only succeeded, amidst several thousand fragments of corals and shells, in finding a few bones of *aquatic* or *amphibious* animals, that we should meet with a single skeleton of an inhabitant of the land?

Clarence, in his dream, saw, "in the slimy bottom of the deep,"

> ——— a thousand fearful wrecks;
> A thousand men, that fishes gnaw'd upon;
> Wedges of gold, great anchors, heaps of pearl.

Had he also beheld, amid "the dead bones that lay scattered by," the carcasses of lions, deer, and the

other wild tenants of the forest and the plain, the fiction would have been deemed unworthy of the genius of Shakspeare. So daring a disregard of probability and violation of analogy would have been condemned as unpardonable, even where the poet was painting those incongruous images which present themselves to a disturbed imagination during the visions of the night.

But, as fossil mammiferous remains have been met with in strata of the more modern periods, it will be desirable to take a rapid view of the contents of successive geological formations, and inquire how far they confirm or invalidate the opinions commonly entertained respecting the doctrine of successive development.

In the first place it should be stated, that faint traces of animal remains make their appearance in strata of as early a date as any in which the impressions of plants have been detected. We are as yet but imperfectly acquainted with the fossils of the deposits called by Werner "transition," or those below the carboniferous series; yet in some of these, as in the limestone of Ludlow, for example, scales and bones of fish have been found.* In these ancient rocks we cannot expect to bring many vertebral remains to light until we have obtained more information respecting the zoophytes and testacea of the same period. The rarer species cannot be discovered until the more abundant have been found again and again; and it may be doubted whether we shall ever succeed in acquiring so extensive a knowledge of the fossil bodies of strata anterior to the coal as to entitle us to attach much importance to the absence of birds and mammalia. In

* Murchison, Proceedings of Geol. Soc. No. 34. p. 13.

rocks of high antiquity many organic forms have been obliterated by various causes, such as subterranean heat and the percolation of acidulous waters, which have operated during a long succession of ages. The number of organic forms which have disappeared from the oldest strata may be conjectured from the fact, that their former existence is in many cases merely revealed to us by the unequal weathering of an exposed face of rock, on which the petrifactions stand out in relief.

If we next consider the old red sandstone, we find that entire skeletons of fish have been discovered in it both in Scotland and in the West of England, and Wales, but no well-authenticated instance is recorded of a fossil reptile from this formation.* Neither have any reptilian remains been met with in the incumbent carboniferous group, either in the mountain limestone, or in the shales and sandstones of the coal. The supposed saurian teeth found by Dr. Hibbert in carboniferous strata near Edinburgh, have been lately shewn by Dr. Agassiz to belong to sauroidal fish, or fish of the highest rank in structure, and approaching more nearly in their osteological characters than any others to true saurians.

It would be premature to conclude that no bones of reptiles are to be found in the carboniferous formation, because it is only within a few years that several dis-

* Scales of a tortoise, nearly allied to Trionyx, are stated in the Geol. Trans. second series, vol. iii. part 1. p. 144., to have been found abundantly in the bituminous schists of Caithness, in Scotland, and in the same formation in the Orkneys. These schists have been shewn by Professor Sedgwick and Mr. Murchison to be of the age of the old red sandstone. But M. Agassiz has lately decided that the scales in question are those of a fish (see figure of them, plate 16., Geol. Trans., same part).

tinct species and genera of fish have been ascertained to abound in the same. It should also be recollected, that if we infer from the fossil flora of the coal, and other circumstances before enumerated, that our latitudes were occupied at the remote period in question by an ocean interspersed with small islands, such islands may, like those of the modern Pacific, have been almost entirely destitute of mammalia and reptiles.*

In regard to birds, they are usually wanting in deposits of all ages, even where fossil animals of the highest order occur in abundance.†

There was evidently a long period, of which the formations from the magnesian limestone to the chalk inclusive may be said to contain the history, when reptiles of various kinds were largely developed on the earth: their remains are particularly numerous in the lias and oolitic strata. As there are now mammalia entirely confined to the land, others which, like the bat and vampyre, fly in the air; others, again, of amphibious habits, which inhabit rivers, like the hippopotamus, otter, and beaver; others exclusively aquatic and marine, like the seal, whale, and narwal, so in the early ages under consideration, there were terrestrial, winged, and aquatic reptiles. There were iguanodons walking on the land, pterodactyles winging their way through the air, monitors and crocodiles in the rivers, and the ichthyosaur and plesiosaur in the ocean. It appears also that some of these ancient saurians approximated more nearly in their organization to the type of living mammalia than do any of our existing reptiles.

I shall not dwell here on a question, which will

* See p. 199.

† See Book iii. ch. 15.

afterwards be discussed more fully, how far the almost entire suppression of one class of vertebrata and the development of another, as, for example, the predominance of reptiles over mammalia, or of these over reptiles, may be reconcileable with the notion of constant and uniform laws governing the distribution of animal life at particular periods.* I shall now merely call the reader's attention to a striking exception to the general rule of the non-occurrence of any signs of warm-blooded quadrupeds in secondary rocks.

In the oolite of Stonesfield, a rock which has been well ascertained to hold a somewhat inferior position in the great oolitic series, the jaws of at least two species of small mammiferous quadrupeds have been found. A specimen of one of these, now in the Oxford Museum (see fig. 2.), was examined by M. Cuvier, and pronounced by him to be allied to the didelphis. According to this naturalist, it was probably a small carnivorous animal not larger than a mole, yet differing from all known carnivora in having ten teeth in a row.

Fig. 2.

Lower jaw of a mammiferous quadruped, from the slate of Stonesfield, near Oxford.†

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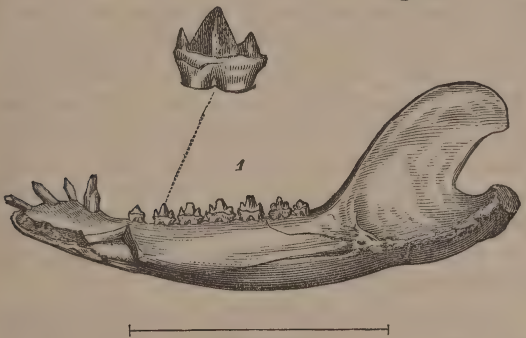
* Book iv. chap. xxiii.

† This figure (No. 2.) is from a drawing by Professor C. Prevost, published Ann. des Sci. Nat., Avril, 1825. The fossil is a lower jaw,

Another specimen now in London, in the collection of Mr. Broderip, consists also of a lower jaw, and belonged certainly to a quadruped of a distinct species, or even genus (see fig. 3.) for the number of teeth is different, and agrees precisely with that of the living didelphis.

Fig. 3.



Natural size.

*Lower jaw of Didelphis Bucklandi, from Stonefield.**

1. The jaw magnified twice in length.
2. The second molar tooth magnified six times.

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adhering by its inner side to the slab of oolite, in which it is sunk. The form of the condyle, or posterior process of the jaw, is distinctly seen, an impression of it being left on the stone, although the bone is wanting. The anterior part of the jaw has been partially broken away, so that the fangs of six molar teeth are seen fixed in their sockets, the form of the fangs being characteristic of the mammalia. The enamel of some of the teeth is well preserved.

* This figure (No. 3.) is taken from the original, in Mr. Broderip's collection. It consists of the right half of a lower jaw, of which the inner side is seen. The jaw contains seven molar teeth, one canine, and three incisors, but the end of the jaw is frac-

The occurrence of these individuals, the most ancient memorials yet known of the mammiferous type, so low down in the oolitic series, while no other representatives of the same class have yet been found in the superior secondary strata, either in the Middle or Upper Oolite, or in the Wealden, Green Sand, or Chalk, is a striking fact, and should serve as a warning to us against hasty generalizations. So important an exception to a general rule may be perfectly consistent with the conclusion, that a small number only of mammalia inhabited European latitudes when our secondary rocks were formed; but it seems fatal to the theory of progressive development, or the notion that the order of precedence in the creation of animals, considered chronologically, coincided with the order in which they would be ranked according to perfection or complexity of structure.

Of the Tertiary strata. — The tertiary strata, as will appear from what has been already stated, were deposited when the physical geography of the northern hemisphere had been entirely altered. Large inland lakes had become numerous, as in Central France and many other countries. There were gulfs of the sea, into which considerable rivers emptied themselves, where strata were formed like those of the Paris basin. There were then also littoral formations in progress,

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tured, and traces of the alveolus of a fourth incisor are seen. With this addition, the number of teeth would agree exactly with those of a lower jaw of a didelphis. The fossil is well preserved in a slab of oolitic structure containing shells of Trigoniæ and other marine remains. Two other jaws, besides those above represented, have been procured from the quarries of Stonesfield. —See Broderip, Zool. Journ. vol. iii. p. 408.

such as are indicated by the English *Crag*, and the *Faluns* of the Loire. The state of preservation of the organic remains of this period is very different from that of fossils in the older rocks, the colours of the shells, and even the cartilaginous ligaments uniting the valves, being in some cases retained. More than 1100 species of testacea have been found in the beds of the Paris basin, and nearly an equal number in the more modern formations of the Subapennine hills; and it is a most curious fact in natural history, that the zoologist has already acquired more extensive information concerning the testacea which inhabited the ancient seas of northern latitudes at those remote epochs than of the species now living in the same parallels in Europe.

Paris basin.—The strata of the Paris basin are partly of freshwater origin, and filled with the spoils of the land. They have afforded a great number of skeletons of land quadrupeds, but these relics are confined almost entirely to one small member of the group, and their conservation may be considered as having arisen from some local and accidental combination of circumstances.* On the other hand, the scarcity of terrestrial mammalia in submarine sediment is elucidated, in a striking manner, by the extremely small number of such remains hitherto procured from the calcaire grossier, one of the formations of the Parisian series.†

London clay—Plastic clay.—The inferior member of our oldest tertiary formation in England, usually termed the plastic clay, has hitherto proved as destitute of mammiferous remains as our ancient coal strata; and this point of resemblance between these deposits

* Book iv. ch. xviii. † Ibid.

is the more worthy of observation, because the lignite, in the one case, and the coal in the other, are exclusively composed of terrestrial plants. From the London clay we have procured three or four hundred species of testacea, but the only bones of vertebrated animals are those of reptiles and fish. On comparing, therefore, the contents of these marine strata with those of our oolitic series, we find the supposed order of precedence inverted. In the more ancient system of rocks, a few mammalia have been recognized; whereas in the newer, if negative evidence were to be our criterion, Nature has made a retrograde, instead of an advancing movement, and no animals more exalted in the scale of organization than reptiles are discoverable. It should, however, be stated, that in a freshwater formation, resting upon the London clay, in the Isle of Wight, and like it belonging to the Eocene epoch, some mammiferous remains have recently been found.

Subapennine beds.—Although the Subapennine strata have been examined by collectors for three hundred years, and have yielded more than a thousand species of testacea, the authenticated examples of imbedded remains of terrestrial mammalia are extremely scanty; and several of those which have been cited by earlier writers as belonging to the elephant or rhinoceros, have since been declared, by competent anatomists, to be the bones of whales and other cetacea. In about five or ten instances, perhaps, bones of the mastodon, rhinoceros, and some other land animals, have been observed in this formation with marine shells attached.

* Buckland and Allan, Jameson's Ed. Phil. Journ., No. 27. p. 190. Pratt, Proceedings of Geol. Soc., No. 18. 1831.

These must have been washed into the bed of the ancient sea when the strata were forming, and they serve to attest the contiguity of land inhabited by large herbivora, which renders the rarity of such exceptions more worthy of attention. On the contrary, the number of skeletons of existing animals in the upper Val d'Arno, which have been usually considered to be referrible to the same age as the Subapennine beds, occur in a deposit which was formed entirely in an inland lake, surrounded by lofty mountains.*

Not a single bone of any quadrumanous animal has ever yet been discovered in a fossil state; and their absence has appeared, to some geologists, to countenance the idea that the type of organization most nearly resembling the human came last in the order of creation, and was scarcely perhaps anterior to that of man. But the evidence on this point is quite inconclusive; for, first, we know nothing of the details of the various classes of the animal kingdom which may have inhabited the land when the secondary strata were accumulated; and in regard to some of the more modern tertiary periods, the climate of Europe does not appear to have been of such a tropical character as may have been necessary for the development of the tribe of apes, monkeys, and allied genera. Besides, it must not be forgotten, that almost all the animals which occur in subaqueous deposits are such as frequent marshes, rivers, or the borders of lakes, as the rhinoceros, tapir, hippopotamus, ox, deer, pig, and others. Species which live in trees are extremely rare in a fossil state; and we have no data as yet for determining how great a number of the one kind we

* See Book iv. ch. xvi.

ought to find, before we have a right to expect a single individual of the other. Even therefore, if we were led to infer, from the presence of crocodiles and turtles in the London clay, and from the cocoa-nuts and spices found in the Isle of Sheppey, that at the period when our older or Eocene tertiary strata were formed, the climate was hot enough for the quadrumanous tribe, we nevertheless could not hope to discover any of their skeletons until we had made considerable progress in ascertaining what were the contemporary Pachydermata; and a very small number of these have, as was before remarked, been hitherto discovered in any strata of this epoch in England.

The result then, of our inquiry into the evidence of the successive development of the animal and vegetable kingdoms, may be stated in a few words. In regard to *plants*, if we neglect the obscure and ambiguous impressions found in some of the oldest fossiliferous rocks, which can lead to no safe conclusions, we may consider those which characterize the great carboniferous group as the first deserving particular attention. They are by no means confined to the simplest forms of vegetation, as to cryptogamic plants; but, on the contrary, belong to all the leading divisions of the vegetable kingdom; some of the more fully developed forms, both of dicotyledons and monocotyledons having already been discovered, even among the first three or four hundred species brought to light: it is therefore superfluous to pursue this part of the argument farther.

If we then examine the animal remains of the oldest formations, we find bones and skeletons of fish in the old red sandstones, and even in some transition

limestones below it; in other words, we have already vertebrated animals in the most ancient strata respecting the fossils of which we can be said to possess any accurate information.

In regard to birds and quadrupeds, their remains are almost entirely wanting in *marine* deposits of every era, even where interposed freshwater strata contain those fossils in abundance, as in the Paris basin. The secondary strata of Europe are for the most part marine, and there is as yet only one instance of the occurrence of mammiferous fossils in them, four or five individuals having been found in the slate of Stonesfield, a rock unquestionably of the oolitic period, and which appears, from several other circumstances, to have been formed near the point where some river entered the sea.

When we examine the tertiary groups, we find in the Eocene or oldest strata of that class the remains of a great assemblage of the highest or mammiferous class, all of extinct species, and in the Miocene beds, or those of a newer tertiary epoch, other forms, for the most part of lost species, and almost entirely distinct from the Eocene tribes. Another change is again perceived, when we investigate the fossils of later or of the Pliocene periods. But in this succession of quadrupeds, we cannot detect any signs of a progressive development of organization,—any indication that the Eocene fauna was less perfect than the Miocene, or the Miocene, than what will be designated in the fourth book the Newer Pliocene.

Recent origin of man. — If then the popular theory of the successive development of the animal and vegetable world, from the simplest to the most perfect forms, rests on a very insecure foundation; it may be

asked, whether the recent origin of man lends any support to the same doctrine, or how far the influence of man may be considered as such a deviation from the analogy of the order of things previously established, as to weaken our confidence in the uniformity of the course of nature.

I need not dwell on the proofs of the low antiquity of our species, for it is not controverted by any experienced geologist; indeed, the real difficulty consists in tracing back the signs of man's existence on the earth to that comparatively modern period when species, now his contemporaries, began to predominate. If there be a difference of opinion respecting the occurrence in certain deposits of the remains of man and his works, it is always in reference to strata confessedly of the most modern order; and it is never pretended that our race co-existed with assemblages of animals and plants, of which *all or even a great part of the species* are extinct. From the concurrent testimony of history and tradition, we learn that parts of Europe, now the most fertile and most completely subjected to the dominion of man, were, less than three thousand years ago, covered with forests, and the abode of wild beasts. The archives of nature are in perfect accordance with historical records; and when we lay open the most superficial covering of peat, we sometimes find therein the canoes of the savage, together with huge antlers of the wild stag, or horns of the wild bull. In caves now open to the day in various parts of Europe, the bones of large beasts of prey occur in abundance; and they indicate that, at periods comparatively modern in the history of the globe, the ascendancy of man, if he existed at all, had scarcely been felt by the brutes.*

* Respecting the probable antiquity assignable to certain human

No inhabitant of the land exposes himself to so many dangers on the waters as man, whether in a savage or a civilized state *; and there is no animal, therefore, whose skeleton is so liable to become imbedded in lacustrine or submarine deposits: nor can it be said that his remains are more perishable than those of other animals; for in ancient fields of battle, as Cuvier has observed, the bones of men have suffered as little decomposition as those of horses which were buried in the same grave.† But even if the more solid parts of our species had disappeared, the impression of their form would have remained engraven on the rocks, as have the traces of the tenderest leaves of plants, and the soft integuments of many animals. Works of art, moreover, composed of the most indestructible materials, would have outlasted almost all the organic contents of sedimentary rocks. Edifices, and even entire cities, have, within the times of history, been buried under volcanic ejections, submerged beneath the sea, or engulphed by earthquakes; and had these catastrophes been repeated throughout an indefinite lapse of ages, the high antiquity of man would have been inscribed in far more legible characters on the framework of the globe than are the forms of the ancient vegetation which once covered the islands of the northern ocean, or of those gigantic reptiles which at still later periods peopled the seas and rivers of the northern hemisphere.‡

Dr. Prichard has argued that the human race have

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bones and works of art found intermixed with remains of extinct animals in several caves in France, see Book iii. ch. xiv.

* See Book iii. ch. xvi. † Ibid.

‡ Ibid.

not always existed on the surface of the earth, because "the strata of which our continents are composed were once a part of the ocean's bed" — "mankind had a beginning, since we can look back to the period when the surface on which they lived began to exist."* This proof, however, is insufficient, for many thousands of human beings now dwell in various quarters of the globe where marine species lived within the times of history, and, on the other hand, the sea now prevails permanently over large districts once inhabited by thousands of human beings. Nor can this interchange of sea and land ever cease while the present causes are in existence. It is conceivable, therefore, that terrestrial species might be older than the continents which they inhabit, and aquatic species of higher antiquity than the lakes and seas which they people.

Doctrine of successive development not confirmed by the admission that man is of modern origin.—It is on other grounds that we are entitled to infer that man is, comparatively speaking, of modern origin; and if this be assumed, we may then ask whether his introduction can be considered as one step in a progressive system, by which, as some suppose, the organic world advanced slowly from a more simple to a more perfect state? In reply to this question, it should first be observed, that the superiority of man depends not on those faculties and attributes which he shares in common with the inferior animals, but on his reason, by which he is distinguished from them. When it is said that the human race is of far higher dignity than were any pre-existing beings on the earth, it is the intellectual and moral attributes only of our race, not the

* Phys. Hist. of Mankind, vol. ii. p. 594.

animal, which are considered; and it is by no means clear, that the organization of man is such as would confer a decided pre-eminence upon him, if, in place of his reasoning powers, he was merely provided with such instincts as are possessed by the lower animals.

If this be admitted, it would by no means follow, even if there had been sufficient geological evidence in favour of the theory of progressive development, that the creation of man was the last link in the same chain. For the sudden passage from an irrational to a rational animal is a phenomenon of a distinct kind from the passage from the more simple to the more perfect forms of animal organization and instinct. To pretend that such a step, or rather leap, can be part of a regular series of changes in the animal world, is to strain analogy beyond all reasonable bounds.

Introduction of man, to what extent a change in the system.—But setting aside the question of progressive development, another and a far more difficult one may arise out of the admission that man is comparatively of modern origin. Is not the interference of the human species, it may be asked, such a deviation from the antecedent course of physical events, that the knowledge of such a fact tends to destroy all our confidence in the uniformity of the order of nature, both in regard to time past and future? If such an innovation could take place after the earth had been exclusively inhabited for thousands of ages by inferior animals, why should not other changes as extraordinary and unprecedented happen from time to time? If one new cause was permitted to supervene, differing in kind and energy from any before in operation, why may not others have come into action at

different epochs? Or what security have we that they may not arise hereafter? And if such be the case, how can the experience of one period, even though we are acquainted with all the possible effects of the then existing causes, be a standard to which we can refer all natural phenomena of other periods?

Now these objections would be unanswerable, if adduced against one who was contending for the absolute uniformity throughout all time of the succession of sublunary events—if, for example, he was disposed to indulge in the philosophical reveries of some Egyptian and Greek sects, who represented all the changes both of the moral and material world as repeated at distant intervals, so as to follow each other in their former connexion of place and time. For they compared the course of events on our globe to astronomical cycles; and not only did they consider all sublunary affairs to be under the influence of the celestial bodies, but they taught that on the earth, as well as in the heavens, the same identical phenomena recurred again and again in a perpetual vicissitude. The same individual men were doomed to be re-born, and to perform the same actions as before; the same arts were to be invented, and the same cities built and destroyed. The Argonautic expedition was destined to sail again with the same heroes, and Achilles with his Myrmidons to renew the combat before the walls of Troy.

> Alter erit tum Tiphys, et altera quæ vehat Argo
> Dilectos heroas: erunt etiam altera bella,
> Atque iterum ad Trojam magnus mittetur Achilles.*

* Virgil, Eclog. iv. For an account of these doctrines, see Dugald Stewart's Elements of the Philosophy of the Human

The geologist, however, may condemn these tenets as absurd, without running into the opposite extreme, and denying that the order of nature has, from the earliest periods, been uniform in the same sense in which we believe it to be uniform at present, and expect it to remain so in future. We have no reason to suppose, that when man first became master of a small part of the globe, a greater change took place in its physical condition than is now experienced when districts, never before inhabited, become successively occupied by new settlers. When a powerful European colony lands on the shores of Australia, and introduces at once those arts which it has required many centuries to mature; when it imports a multitude of plants and large animals from the opposite extremity of the earth, and begins rapidly to extirpate many of the indigenous species, a mightier revolution is effected in a brief period than the first entrance of a savage horde, or their continued occupation of the country for many centuries, can possibly be imagined to have produced. If there be no impropriety in assuming that the system is uniform when disturbances so unprecedented occur in certain localities, we can with much greater confidence apply the same language to those primeval ages when the aggregate number and power of the human race, or the rate of their advancement in civilization, must be supposed to have been far inferior. In reasoning on the state of the globe immediately before our species was called into existence, we must be guided by the same rules of induction as when we speculate on the state of America in the interval that

Mind, vol. ii. chap. ii. sect. 4., and Prichard's Egypt. Mythol. p. 177.

elapsed between the introduction of man into Asia, the supposed cradle of our race, and the arrival of the first adventurers on the shores of the New World. In that interval, we imagine the state of things to have gone on according to the order now observed in regions unoccupied by man. Even now, the waters of lakes, seas, and the great ocean, which teem with life, may be said to have no immediate relation to the human race — to be portions of the terrestrial system of which man has never taken, nor ever can take, possession; so that the greater part of the inhabited surface of the planet may remain still as insensible to our presence as before any isle or continent was appointed to be our residence.

If the barren soil around Sydney had at once become fertile upon the landing of our first settlers; if, like the happy isles whereof the poets have given us such glowing descriptions, those sandy tracts had begun to yield spontaneously an annual supply of grain, we might then, indeed, have fancied alterations still more remarkable in the economy of nature to have attended the first coming of our species into the planet. Or if, when a volcanic island like Ischia was, for the first time, brought under cultivation by the enterprise and industry of a Greek colony, the internal fire had become dormant, and the earthquake had remitted its destructive violence, there would then have been some ground for speculating on the debilitation of the subterranean forces, when the earth was first placed under the dominion of man. But after a long interval of rest, the volcano bursts forth again with renewed energy, annihilates one half of the inhabitants, and compels the remainder to emigrate. The course of nature remains evidently unchanged; and, in like

manner, we may suppose the general condition of the globe, immediately before and after the period when our species first began to exist, to have been the same, with the exception only of man's presence.

The modifications in the system of which man is the instrument, do not, perhaps, constitute so great a deviation from previous analogy as we usually imagine; we often, for example, form an exaggerated estimate of the extent of our power in extirpating some of the inferior animals, and causing others to multiply; a power which is circumscribed within certain limits, and which, in all likelihood, is by no means exclusively exerted by our species.* The growth of human population cannot take place without diminishing the numbers, or causing the entire destruction, of many animals. The larger carnivorous species give way before us, but other quadrupeds of smaller size, and innumerable birds, insects, and plants, which are inimical to our interests, increase in spite of us, some attacking our food, others our raiment and persons, and others interfering with our agricultural and horticultural labours. We behold the rich harvest which we have raised with the sweat of our brow devoured by myriads of insects, and are often as incapable of arresting their depredations, as of staying the shock of an earthquake, or the course of a stream of lava.

A great philosopher has observed, that we can command nature only by obeying her laws; and this principle is true even in regard to the astonishing changes which are superinduced in the qualities of certain animals and plants by domestication and garden culture. I shall point out in the third book that we can

* See Book iii. ch. ix.

only effect such surprising alterations by assisting the development of certain instincts, or by availing ourselves of that mysterious law of their organization, by which individual peculiarities are transmissible from one generation to another.*

It is probable from these, and many other considerations, that as we enlarge our knowledge of the system, we shall become more and more convinced, that the alterations caused by the interference of man deviate far less from the analogy of those effected by other animals than is usually supposed.† We are often misled, when we institute such comparisons, by our knowledge of the wide distinction between the instincts of animals and the reasoning power of man; and we are apt hastily to infer, that the effects of a rational and an irrational species, considered merely *as physical agents*, will differ almost as much as the faculties by which their actions are directed.

It is not, however, intended that a real departure from the antecedent course of physical events cannot be traced in the introduction of man. If that latitude of action which enables the brutes to accommodate themselves in some measure to accidental circumstances, could be imagined to have been at any former period so great, that the operations of instinct were as much diversified as are those of human reason, it might, perhaps, be contended, that the agency of man did not constitute an anomalous deviation from the previously established order of things. It might then have been said, that the earth's becoming at a particular period the residence of human beings, was an era in the

* See Book iii. ch. iii.

† Id. chapters v. vi. vii. and ix.

moral, not in the physical world — that our study and contemplation of the earth, and the laws which govern its animate productions, ought no more to be considered in the light of a disturbance or deviation from the system, than the discovery of the satellites of Jupiter should be regarded as a physical event affecting those heavenly bodies. Their influence in advancing the progress of science among men, and in aiding navigation and commerce, was accompanied by no reciprocal action of the human mind upon the economy of nature in those distant planets; and so the earth might be conceived to have become, at a certain period, a place of moral discipline, and intellectual improvement to man, without the slightest derangement of a previously existing order of change in its animate and inanimate productions.

The distinctness, however, of the human from all other species, considered merely as an efficient cause in the physical world, is real; for we stand in a relation to contemporary species of animals and plants widely different from that which other irrational animals can ever be supposed to have held to each other. We modify their instincts, relative numbers, and geographical distribution, in a manner superior in degree, and in some respects very different in kind, from that in which any other species can affect the rest. Besides, the progressive movement of each successive generation of men causes the human species to differ more from itself in power at two distant periods, than any one species of the higher order of animals differs from another. The establishment, therefore, by geological evidence, of the first intervention of such a peculiar and unprecedented agency, long after other

parts of the animate and inanimate world existed, affords ground for concluding that the experience during thousands of ages of all the events which may happen on this globe would not enable a philosopher to speculate with confidence concerning future contingencies.

If then an intelligent being, after observing the order of events for an indefinite series of ages, had witnessed at last so wonderful an innovation as this, to what extent would his belief in the regularity of the system be weakened? — would he cease to assume that there was permanency in the laws of nature? — would he no longer be guided in his speculations by the strictest rules of induction? To these questions it may be answered, that, had he previously presumed to dogmatize respecting the absolute uniformity of the order of nature, he would undoubtedly be checked by witnessing this new and unexpected event, and would form a more just estimate of the limited range of his own knowledge, and the unbounded extent of the scheme of the universe. But he would soon perceive that no one of the fixed and constant laws of the animate or inanimate world was subverted by human agency, and that the modifications produced were on the occurrence of new and extraordinary circumstances, and those not of a *physical* but a *moral* nature. The deviation permitted would also appear to be as slight as was consistent with the accomplishment of the new *moral* ends proposed, and to be in a great degree temporary in its nature, so that, whenever the power of the new agent was withheld, even for a brief period, a relapse would take place to the ancient state of things; the domesticated animal, for example, recovering in a few generations its wild instinct, and the

garden-flower and fruit-tree reverting to the likeness of the parent stock.

Now, if it would be reasonable to draw such inferences with respect to the future, we cannot but apply the same rules of induction to the past. We have no right to anticipate any modifications in the results of existing causes in time to come, which are not conformable to analogy, unless they be produced by the progressive development of human power, or perhaps by some other new relations which may hereafter spring up between the moral and material worlds. In the same manner, when we speculate on the vicissitudes of the animate and inanimate creation in former ages, we ought not to look for any anomalous results, unless where man has interfered, or unless clear indications appear of some other *moral* source of temporary derangement.

For the discussion of other popular objections advanced against the doctrine of the identity of the ancient and modern causes of change, especially those founded on the supposed suddenness of general catastrophes, and the transition from one set of organic remains to another, I must refer to the 4th Book. In the mean time, when difficulties arise in interpreting the monuments of the past, I deem it more consistent with philosophical caution to refer them to our present ignorance of all the existing agents, or all their possible effects in an indefinite lapse of time, than to causes formerly in operation, but which have ceased to act; and if in any part of the globe the energy of a cause appears to have decreased, I consider it more probable that the diminution of intensity in its action is merely local, than that its force is impaired throughout the whole globe. But should there appear reason to be-

lieve that certain agents have, at particular periods of past time, been more potent instruments of change over the entire surface of the earth than they now are, it is still more consistent with analogy to presume, that after an interval of quiescence they will recover their pristine vigour, than to imagine that they are worn out.

The geologist who assents to the truth of these principles will deem it incumbent on him to examine with minute attention all the changes now in progress on the earth, and will regard every fact collected respecting the causes in diurnal action, as affording him a key to the interpretation of some mystery in the archives of remote ages. His estimate of the value of geological evidence, and his interest in the investigation of the earth's history, will depend entirely on the degree of confidence which he feels in regard to the permanency of the great causes of change. Their constancy alone will enable him to reason from analogy, and to arrive, by a comparison of the state of things at distinct epochs, at the knowledge of the general laws which govern the economy of our system.

The uniformity of the plan being once assumed, events which have occurred at the most distant periods in the animate and inanimate world will be acknowledged to throw light on each other, and the deficiency of our information respecting some of the most obscure parts of the present creation will be removed. For as, by studying the external configuration of the existing land and its inhabitants, we may restore in imagination the appearance of the ancient continents which have passed away, so may we obtain from the deposits of ancient seas and lakes an insight into the nature of the

subaqueous processes now in operation, and of many forms of organic life, which, though now existing, are veiled from sight. Rocks, also, produced by subterranean fire in former ages at great depths in the bowels of the earth, present us, when upraised by gradual movements, and exposed to the light of heaven, with an image of those changes which the deep-seated volcano may now occasion in the nether regions. Thus, although we are mere sojourners on the surface of the planet, chained to a mere point in space, enduring but for a moment of time, the human mind is not only enabled to number worlds beyond the unassisted ken of mortal eye, but to trace the events of indefinite ages before the creation of our race, and is not even withheld from penetrating into the dark secrets of the ocean, or the interior of the solid globe; free, like the spirit which the poet described as animating the universe,

> ——— ire per omnes
> Terrasque, tractusque maris, cœlumque profundum.

BOOK II.

CHANGES OF THE INORGANIC WORLD.

Aqueous Causes.

CHAPTER I.

Division of the subject into changes of the organic and inorganic world — Inorganic causes of change divided into aqueous and igneous — Aqueous causes first considered — Destroying and transporting power of running water — Sinuosities of rivers — Two streams when united do not occupy a bed of double surface (p. 261.) — Heavy matter removed by torrents and floods — Recent inundations in Scotland — Effects of glaciers and icebergs in removing stones — Erosion of chasms through hard rocks (p. 268.) — Excavations in the lavas of Etna by Sicilian rivers — Gorge of the Simeto — Gradual recession of the cataracts of Niagara.

Division of the subject. — Geology was defined to be the science which investigates the former changes that have taken place in the organic, as well as in the inorganic kingdoms of nature; and we may next proceed to inquire what changes are now in progress in both these departments. Vicissitudes in the inorganic world are most apparent; and as on them all fluctuations in the animate creation must in a great measure depend, they may claim our first consideration. The great agents of change in the inorganic world may be divided into two principal classes, the aqueous and the igneous. To the aqueous belong Rivers,

Torrents, Springs, Currents, and Tides; to the igneous, Volcanos and Earthquakes. Both these classes are instruments of decay as well as of reproduction; but they may also be regarded as antagonist forces. For the aqueous agents are incessantly labouring to reduce the inequalities of the earth's surface to a level; while the igneous are equally active in restoring the unevenness of the external crust, partly by heaping up new matter in certain localities, and partly by depressing one portion, and forcing out another, of the earth's envelope.

It is difficult, in a scientific arrangement, to give an accurate view of the combined effects of so many forces in simultaneous operation; because, when we consider them separately, we cannot easily estimate either the extent of their efficacy, or the kind of results which they produce. We are in danger, therefore, when we attempt to examine the influence exerted singly by each, of overlooking the modifications which they produce on one another; and these are so complicated, that sometimes the igneous and aqueous forces co-operate to produce a joint effect, to which neither of them unaided by the other could give rise, — as when repeated earthquakes unite with running water to widen a valley; or when a thermal spring rises up from a great depth, and conveys the mineral ingredients with which it is impregnated from the interior of the earth to the surface. Sometimes the organic combine with the inorganic causes; as when a reef, composed of shells and corals, protects one line of coast from the destroying power of tides or currents, and turns them against some other point; or when drift timber, floated into a lake, fills a hollow to which

the stream would not have had sufficient velocity to convey earthy sediment.

It is necessary, however, to divide our observations on these various causes, and to classify them systematically, endeavouring as much as possible to keep in view that the effects in nature are mixed, and not simple, as they may appear in an artificial arrangement.

In treating, in the first place, of the aqueous causes, we may consider them under two divisions: first, those which are connected with the circulation of water from the land to the sea, under which are included all the phenomena of rivers and springs; secondly, those which arise from the movements of water in lakes, seas, and the ocean, wherein are comprised the phenomena of tides and currents. In turning our attention to the former division, we find that the effects of rivers may be subdivided into those of a destroying and those of a renovating nature; in the destroying are included the erosion of rocks, and the transportation of matter to lower levels; in the renovating class, the formation of deltas by the influx of sediment, and the shallowing of seas.

Action of running water. — I shall begin, then, by describing the destroying and transporting power of running water, as exhibited by torrents and rivers. It is well known that the lands elevated above the sea attract, in proportion to their volume and density, a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and the ocean. By these means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. In consequence of this provision, almost all

the water is first carried to the highest regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil, than it would do if the rain had been distributed over the plains and mountains equally in proportion to their relative areas. Almost all the water is also made by these means to pass over the greatest distances which each region affords, before it can regain the sea. The rocks also, in the higher regions, are particularly exposed to atmospheric influences, to frost, rain, and vapour, and to great annual alternations of cold and heat, of moisture and desiccation.

Its destroying and transporting power.—Among the most powerful agents of decay may be mentioned that property of water which causes it to expand during congelation; so that, when it has penetrated into the crevices of the most solid rocks, it rends them open on freezing with mechanical force. For this reason, although in cold climates the comparative quantity of rain which falls is very inferior, and although it descends more gradually than in tropical regions, yet the severity of frost, and the greater inequalities of temperature, compensate in some degree for this diminished source of degradation. The solvent power of water also is very great, and acts particularly on the calcareous and alkaline elements of stone, especially when it holds carbonic acid in solution, which is abundantly supplied to almost every large river by springs, and is collected by rain from the atmosphere. The oxygen of the atmosphere is also gradually absorbed by all animal and vegetable productions, and by almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, and

tends to reduce into powder, and to render fit for soils, even the hardest aggregates belonging to our globe.*

When earthy matter has once been intermixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a stream. Running water charged with foreign ingredients being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream. The obstruction causes a temporary increase of the water, which then sweeps down the barrier.

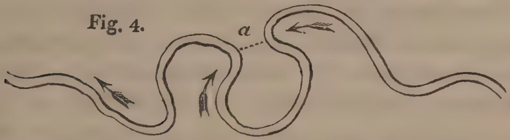
Sinuosities of Rivers.—By a repetition of these landslips, the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded, tends partly to give new directions to the lateral force of excavation. When by these, or by accidental shiftings of the alluvial matter in the channel, and numerous other causes, the current is made to cross its general line of descent, it eats out a curve in the opposite bank, or in the side of the hills bounding the valley, from which curve it is turned back again at an equal angle, so that it recrosses the line of descent, and gradually hollows out another curve lower down in the opposite bank, till the whole sides of the valley, or river-bed, present a succession of salient and retiring angles. Among the causes of deviation from a straight course by which torrents and rivers tend in mountainous regions to widen the valleys through which they flow, may be mentioned the confluence of lateral torrents, swollen irregularly at dif-

* Sir H. Davy, Consolations in Travel, p. 271.

ferent seasons by partial storms, and discharging at different times unequal quantities of debris into the main channel.

When the tortuous flexures of a river are extremely great, the aberration from the direct line of descent is often restored by the river cutting through the isthmus which separates two neighbouring curves. Thus, in the annexed diagram, the extreme sinuosity of the

Fig. 4.



river has caused it to return for a brief space in a contrary direction to its main course, so that a peninsula is formed, and the isthmus (at *a*) is consumed on both sides by currents flowing in opposite directions. In this case an island is soon formed,—on either side of which a portion of the stream usually remains.* These windings occur not only in the channels of rivers, flowing like the Mississippi through flat alluvial plains, but large valleys also are excavated to a great depth through solid rocks in this serpentine form. In the valley of the Moselle, between Berncastle and Roarn, which is sunk to a depth of from six to eight hundred feet through an elevated platform of transition rocks, the curves are so considerable that the river returns, after a course of seventeen miles in one instance, and nearly as much in two others, to within a distance of a few hundred yards of the spot it passed before.†

* See a Paper on the Excavation of Valleys, &c. by G. Poulett Scrope, Esq. Proceedings of Geol. Soc. No. 14., 1830.

† Ibid.

The valley of the Meuse, near Givet, and many others in different countries, offer similar windings. Mr. Scrope has remarked, that these tortuous flexures are decisively opposed to the hypothesis, that any violent and transient rush of water suddenly swept out such valleys; for great floods would produce straight channels in the direction of the current, not sinuous excavations, wherein rivers flow back again in an opposite direction to their general line of descent.

I cannot however accede to the doctrine, that the valleys of the Meuse and Moselle above alluded to were formed simply by river action; believing them, like many other deep valleys of a similar form, to have been principally due to the tides and currents of the sea, which acted throughout a great lapse of ages during the gradual elevation of the country.*

Transporting power of water.— In regard to the transporting power of water, we may often be surprised at the facility with which streams of a small size, and descending a slight declivity, bear along coarse sand and gravel; for we usually estimate the weight of rocks in air, and do not reflect on their comparative buoyancy when submerged in a denser fluid. The specific gravity of many rocks is not more than twice that of water, and very rarely more than thrice, so that almost all the fragments propelled by a stream have lost a third, and many of them half, of what we usually term their weight.

It has been proved by experiment, in contradiction to the theories of the earlier writers on hydrostatics, to be a universal law, regulating the motion of running

* For remarks on the valley of the Meuse, near St. Mihiel, alluded to in this place in a former edition, see Book iv. Ch. x.

water, that the velocity at the bottom of the stream is every where less than in any part above it, and is greatest at the surface. Also, that the superficial particles in the middle of the stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction; and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second at the bottom is ascertained to be sufficient to tear up fine clay,—six inches per second, fine sand,—twelve inches per second, fine gravel,—and three feet per second, stones of the size of an egg.*

When this mechanical power of running water is considered, we are prepared for the transportation of large quantities of gravel, sand, and mud, by the torrents and rivers which descend with great velocity from mountainous regions. But a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea. If they had not this removing power, their channels would be annually choked up, and the valleys of the lower country, and plains at the base of mountain-chains would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of running water—that two equal streams do not, when united, occupy a bed of double surface. In other words, when several rivers unite into one, the super-

* Encyc. Brit. —art. Rivers.

ficial area of the fluid mass is far less than that previously occupied by the separate streams. The collective waters, instead of spreading themselves out over a larger horizontal space, contract themselves into a column of which the height is greater relatively to its breadth. Hence a smaller proportion of the whole is retarded by friction against the bottom and sides of the channel; and in this manner the main current is often accelerated in the lower country, even where the slope of the river's bed is lessened.

It not unfrequently happens, as will be afterwards demonstrated by examples, that two large rivers, after their junction, have only the *surface* which one of them had previously; and even in some cases their united waters are confined in a narrower bed than each of them filled before. By this beautiful adjustment, the water which drains the interior country is made continually to occupy less room as it approaches the sea; and thus the most valuable part of our continents, the rich deltas, and great alluvial plains, are prevented from being constantly under water.*

Floods in Scotland, 1829.—Many remarkable illustrations of the power of running water in moving stones and heavy materials were afforded by the storm and flood which occurred on the 3d and 4th of August, 1829, in Aberdeenshire and other counties in Scotland. The elements during this storm assumed all the characters which mark the tropical hurricanes; the wind blowing in sudden gusts and whirlwinds, the lightning and thunder being such as is rarely witnessed in our climate, and heavy rain falling without intermission. The floods extended almost simultaneously, and with

* See article Rivers, Encyc. Brit.

equal violence, over that part of the north-east of Scotland which would be cut off by two lines drawn from the head of Lochrannoch, one towards Inverness and the other to Stonehaven. The united line of the different rivers which were flooded could not be less than from five to six hundred miles in length; and the whole of their courses were marked by the destruction of bridges, roads, crops, and buildings. Sir T. D. Lauder has recorded the destruction of thirty-eight bridges, and the entire obliteration of a great number of farms and hamlets. On the Nairn, a fragment of sandstone, fourteen feet long by three feet wide and one foot thick, was carried above two hundred yards down the river. Some new ravines were formed on the sides of mountains where no streams had previously flowed, and ancient river-channels, which had never been filled from time immemorial, gave passage to a copious flood.*

The bridge over the Dee at Ballatu consisted of five arches, having upon the whole a water-way of 260 feet. The bed of the river, on which the piers rested, was composed of rolled pieces of granite and gneiss. The bridge was built of granite, and had stood uninjured for twenty years; but the different parts were swept away in succession by the flood, and the whole mass of masonry disappeared in the bed of the river.† "The river Don," observes Mr. Farquharson, in his account of the inundations, "has upon my own pre-

* Sir T. D. Lauder's Account of the Great Floods in Morayshire, Aug. 1829.

† From the account given by the Rev. James Farquharson, in the Quarterly Journ. of Science, &c. No. xii. New Series, p. 328.

mises forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds weight, up an inclined plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep, on a flat ground;—the heap ends abruptly at its lower extremity."*

The power even of a small rivulet, when swoln by rain, in removing heavy bodies, was lately exemplified in the College, a small stream which flows at a moderate declivity from the eastern water-shed of the Cheviot-Hills. Several thousand tons' weight of gravel and sand were transported to the plain of the Till, and a bridge then in progress of building was carried away, some of the arch-stones of which, weighing from half to three quarters of a ton each, were propelled two miles down the rivulet. On the same occasion, the current tore away from the abutment of a mill-dam a large block of greenstone-porphyry, weighing nearly two tons, and transported it to the distance of a quarter of a mile. Instances are related as occurring repeatedly, in which from one to three thousand tons of gravel are, in like manner, removed by this streamlet to still greater distances in one day.†

In the cases above adverted to, the waters of the river and torrent were dammed back by the bridges, which acted as partial barriers, and illustrate the irresistible force of a current when obstructed. Bridges are also liable to be destroyed by the tendency of rivers to shift their course, whereby the pier, or the rock on which the foundation stands, is undermined.

* Quarterly Journ. of Sci. &c. No. xii. New Series, p. 331.

† See a paper by Mr. Culley, F.G.S., Proceedings of Geol. Soc. No. 12. 1829.

When we consider how insignificant are the volume and velocity of the rivers and streams in our island, when compared to those of the Alps and other lofty chains, and how, during the successive changes which the levels of various districts have undergone, the contingencies which give rise to floods must have been multiplied, we may easily conceive that the quantity of loose superficial matter distributed over Europe must be considerable. That the position also of a great portion of these travelled materials should now appear most irregular, and should often bear no relation to the existing water-drainage of the country, is a necessary consequence, as we shall afterwards see, of the combined operations of running water and subterranean movements.

Effects of ice in removing stones.—In mountainous regions and high northern latitudes, the moving of heavy stones by water is greatly assisted by the ice which adheres to them, and which, forming together with the rock a mass of less specific gravity, is readily borne along.* The snow which falls on the summits of the Alps throughout nine months of the year is drifted into the higher valleys, and being pressed downward by its own weight, forms those masses of ice and snow called *glaciers*. Large portions of these often descend into the lower valleys, where they are seen in the midst of forests and green pastures. The mean depth of the glaciers descending from Mont Blanc is from 80 to 100 feet, and in some chasms is seen to amount to 600 feet.† The surface of the moving mass is usually loaded with sand and large stones,

* Silliman's Journal, No. xxx. p. 303.

† Saussure, Voy. dans les Alpes, tom. i. p. 440.

derived from the disintegration of the surrounding rocks acted upon by frost. These transported materials are generally arranged in long ridges or mounds, sometimes thirty or forty feet high. They are often two, three, or even more in number, like so many lines of intrenchment, and consist of the debris which have been brought in by lateral glaciers. The whole accumulation is called in Switzerland "the moraine," which is slowly conveyed to inferior valleys, and left where the snow and ice melt, upon the plain, the larger blocks remaining, and the smaller being swept away by the stream to which the melting of the ice gives rise. This stream flows along the bottom of each glacier, issuing from an arch at its lower extremity.

In northern latitudes, where glaciers descend into valleys terminating in the sea, great masses of ice, on arriving at the shore, are occasionally detached and floated off together with their "moraine." The currents of the ocean are then often instrumental in transporting them to great distances. Scoresby counted 500 icebergs drifting along in latitude 69° and 70° north, which rose above the surface from the height of one to two hundred feet, and measured from a few yards to a mile in circumference.* Many of these contained strata of earth and stones, or were loaded with beds of rock of great thickness, of which the weight was conjectured to be from fifty thousand to one hundred thousand tons. Such bergs must be of great magnitude; because the mass of ice below the level of the water is between seven and eight times greater than that above. Wherever they are

* Voyage in 1822, p. 233.

dissolved, it is evident that the "moraine" will fall to the bottom of the sea. In this manner may submarine valleys, mountains, and platforms become strewed over with scattered blocks of foreign rock, of a nature perfectly dissimilar from all in the vicinity, and which may have been transported across unfathomable abysses. We have before stated, that some ice islands have been known to drift from Baffin's Bay to the Azores, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope.*

M. Lariviere relates that, being at Memel, on the Baltic, in 1821, when the ice of the river Niemen broke up, he saw a glacier thirty feet long, which had descended the stream, and had been thrown ashore. In the middle of it was a triangular piece of granite about a yard in diameter, resembling in composition the red granite of Finland.† Many rocky fragments are in this manner introduced by rivers into the Baltic; and some of much larger dimensions are carried annually by the ice from one place to another in the Gulf of Bothnia, where the sea freezes every winter to the depth of five or six feet. Blocks of stone resting on shoals are first frozen in, and then on the melting of the snow as summer approaches, when the waters of the gulf rise about three feet, they are lifted up and conveyed to great distances by the ice, which in that season has broken up into floating islands.

Excavation of rocks by running water.—The rapidity with which even the smallest streams hollow out deep channels in soft and destructible soils is re-

* For farther remarks on the transporting power of glaciers, see Book iv. ch. 11.

† Consid. sur les Blocs Errat., 1829.

markably exemplified in volcanic countries, where the sand and half-consolidated tuffs oppose but a slight resistance to the torrents which descend the mountain side. After the heavy rains which followed the eruption of Vesuvius in 1822, the water flowing from the Atrio del Cavallo cut, in three days, a new chasm through strata of tuff and ejected volcanic matter, to the depth of twenty-five feet. I found the old mule-road, in 1828, intersected by this new ravine.

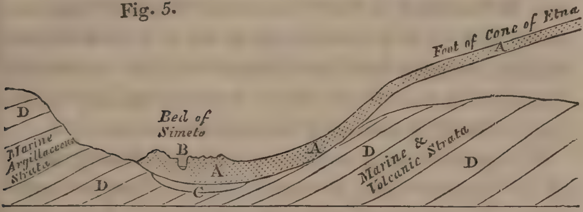
The gradual erosion of deep chasms through some of the hardest rocks, by the constant passage of running water charged with foreign matter, is another phenomenon of which striking examples may be adduced. Illustrations of this excavating power are presented by many valleys in central France, where the channels of rivers have been barred up by solid currents of lava, through which the streams have re-excavated a passage to the depth of from twenty to seventy feet and upwards, and often of great width. In these cases there are decisive proofs that neither the sea, nor any denuding wave or extraordinary body of water, has passed over the spot since the melted lava was consolidated. Every hypothesis of the intervention of sudden and violent agency is entirely excluded, because the cones of *loose* scoriæ, out of which the lavas flowed, are oftentimes at no great elevation above the rivers, and have remained undisturbed during the whole period which has been sufficient for the hollowing out of such enormous ravines.*

Recent excavation by the Simeto.—But I shall at present confine myself to examples derived from events which have happened since the time of history.

* See Book iv. ch. 19.

At the western base of Etna, a great current of lava (A A, fig. 5.), descending from near the summit of the great volcano, has flowed to the distance of five

Fig. 5.



Recent excavation of lava at the foot of Etna by the river Simeto.

or six miles, and then reached the alluvial plain of the Simeto, the largest of the Sicilian rivers, which skirts the base of Etna, and falls into the sea a few miles south of Catania. The lava entered the river about three miles above the town of Aderno, and not only occupied its channel for some distance, but, crossing to the opposite side of the valley, accumulated there in a rocky mass. Gemmellaro gives the year 1603 as the date of the eruption.* The appearance of the current clearly proves that it is one of the most modern of those of Etna: for it has not been covered or crossed by subsequent streams or ejections, and the olives on its surface are all of small size, yet older than the natural wood on the same lava. In the course, therefore, of about two centuries, the Simeto has eroded a passage from fifty to several hundred feet wide, and in some parts from forty to fifty feet deep.

The portion of lava cut through is in no part porous

* Quadro Istorico dell' Etna, 1824. Some doubts are entertained as to the exact date of this current by others, but all agree that it is not one of the older streams even of the historical era.

or scoriaceous, but consists of a compact homogeneous mass of hard blue rock, somewhat inferior in weight to ordinary basalt, and containing crystals of olivine and glassy felspar. The general declivity of this part of the bed of the Simeto is not considerable; but, in consequence of the unequal waste of the lava, two waterfalls occur at Passo Manzanelli, each about six feet in height. Here the chasm (B, fig. 5.) is about forty feet deep, and only fifty broad.

The sand and pebbles in the river-bed consist chiefly of a brown quartzose sandstone, derived from the upper country; but the materials of the volcanic rock itself must have greatly assisted the attrition. This river, like the Caltabiano on the eastern side of Etna, has not yet cut down to the ancient bed of which it was dispossessed, and of which the probable position is indicated in the annexed diagram (C, fig. 5.).

On entering the narrow ravine where the water foams down the two cataracts, we are entirely shut out from all view of the surrounding country; and a geologist who is accustomed to associate the characteristic features of the landscape with the relative age of certain rocks, can scarcely dissuade himself from the belief that he is contemplating a scene in some rocky gorge of a primary district. The external forms of the hard blue lava are as massive as any of the most ancient trap-rocks of Scotland. The solid surface is in some parts smoothed and almost polished by attrition, and covered in others with a white lichen, which imparts to it an air of extreme antiquity, so as greatly to heighten the delusion. But the moment we re-ascend the cliff the spell is broken: for we scarcely recede a few paces, before the ravine and river disappear, and we stand on the black and rugged surface of a vast

current of lava, which seems unbroken, and which we can trace up nearly to the distant summit of that majestic cone which Pindar called "the pillar of heaven," and which still continues to send forth a fleecy wreath of vapour, reminding us that its fires are not extinct, and that it may again give out a rocky stream, wherein other scenes like that now described may present themselves to future observers.

Falls of Niagara. — The falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. That river flows from Lake Erie to Lake Ontario, the former lake being 330 feet above the latter, and the distance between them being thirty-two miles. On flowing out of the upper lake, the river is almost on a level with its banks; so that, if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the West, and of the State of New York on the East.* The river, where it issues, is about three quarters of a mile in width. Before reaching the falls, it is propelled with great rapidity, being a mile broad, about twenty-five feet deep, and having a descent of fifty feet in half a mile. An island at the very verge of the cataract divides it into two sheets of water; one of these, called the Horse-shoe Fall, is six hundred yards wide, and 158 feet perpendicular; the other, called the American Falls, is about two hundred yards in width, and 164 feet in height. The breadth of the island is about five hundred yards. This great sheet of water is precipitated over a ledge of hard limestone, in horizontal

* Captain Hall's Travels in North America, vol. i. p. 179.

strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the calcareous rock forms an overhanging mass, projecting forty feet or more above the hollow space below.

The blasts of wind, charged with spray, which rise out of the pool into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant; and the superincumbent limestone, being left without a foundation, falls from time to time in rocky masses. When these enormous fragments descend, a shock is felt at some distance, accompanied by a noise like a distant clap of thunder. After the river has passed over the falls, its character, observes Captain Hall, is immediately and completely changed. It then runs furiously along the bottom of a deep wall-sided valley, or huge trench, which has been cut into the horizontal strata by the continued action of the stream during the lapse of ages. The cliffs on both sides are in most places perpendicular, and the ravine is only perceived on approaching the edge of the precipice.*

The waters, which expand at the falls, where they are divided by the island, are contracted again, after their union, into a stream not more than 160 yards broad. In the narrow channel, immediately below this immense rush of water, a boat can pass across the stream with ease. The pool, it is said, into which the cataract is precipitated, being 170 feet deep, the descending water sinks down and forms an under-current,

* Captain Hall's Travels in North America, vol. i. pp. 195, 196. 216.

while a superficial eddy carries the upper stratum back *towards* the main fall.* This is not improbable; and we must also suppose, that the confluence of the two streams, which meet at a considerable angle, tends mutually to neutralize their forces. The bed of the river below the falls is strewed over with huge fragments which have been hurled down into the abyss. By the continued destruction of the rocks, the falls have, within the last forty years, receded nearly fifty yards, or, in other words, the ravine has been prolonged to that extent. Through this deep chasm, the Niagara flows for about seven miles; and then the table-land, which is almost on a level with Lake Erie, suddenly sinks down at a town called Queenstown, and the river emerges from the ravine into a plain, which continues to the shores of Lake Ontario.†

Recession of the Falls. — There seems good foundation for the general opinion, that the falls were once at Queenstown, and that they have gradually retrograded from that place to their present position, about seven miles distant. The table-land, extending from thence to Lake Erie, consists uniformly of the same geological formations as are now exposed to view at the falls. The upper stratum is an ancient alluvial sand, varying in thickness from 10 to 140 feet; below which is a bed of hard limestone, about ninety feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river *above*

* See Mr. Bakewell, jun. on the falls of Niagara.— Loudon's Mag. of Nat. Hist. No. xii. March, 1830.

† The memoir of Mr. Bakewell, jun., above referred to, contains two very illustrative sketches of the physical geography of the country between Lakes Erie and Ontario, including the Falls.

the falls, as do the inferior shales *below.* The lower shale is nearly of the same thickness as the limestone; but this last is said to thicken at the point now reached by the falls, a circumstance which may enable it in future to offer greater resistance to the force of the cataract.*

If the ratio of recession had never exceeded fifty yards in forty years, it must have required nearly ten thousand years for the excavation of the whole ravine; but scarcely any estimate can be formed of the quantity of time consumed in such an operation, because the retrograde movement was probably much more rapid when the whole current was confined within a space not exceeding a fourth or fifth of that which the falls now occupy. Should the erosive action not be accelerated in future, it will require upwards of thirty thousand years for the falls to reach Lake Erie (twenty-five miles distant), to which they seem destined to arrive in the course of time, unless some earthquake changes the relative levels of the district.

If that great lake should remain in its present state until the period when the ravine recedes to its shores, the sudden escape of so vast a body of water might cause a tremendous deluge; for the ravine would be much more than sufficient to drain the whole lake, of which the average depth was found, during the late survey, to be only 10 or 12 fathoms. But, in consequence of its shallowness, Lake Erie is fast filling up with sediment; and it may be questioned, whether its entire area may not be converted into dry land, before the falls recede so far.

* Monthly American Journ. July, 1831, p. 21.

CHAPTER II.

ACTION OF RUNNING WATER — *continued.*

Course of the Po — Desertion of its old channel — Artificial embankments of the Po, Adige, and other Italian rivers — Basin of the Mississippi — Its meanders — Islands — Shifting of its course — Raft of the Atchafalaya (p. 282.) — Drift wood — New-formed lakes in Louisiana — Earthquakes in valley of Mississippi — Floods caused by land-slips in the White Mountains (p. 289.) — Bursting of a lake in Switzerland — Devastations caused by the Anio at Tivoli.

Course of the Po. — The Po affords an instructive example of the manner in which a great river bears down to the sea the matter poured into it by a multitude of tributaries descending from lofty chains of mountains. The changes gradually effected in the great plain of Northern Italy, since the time of the Roman republic, are considerable. Extensive lakes and marshes have been gradually filled up, as those near Placentia, Parma, and Cremona, and many have been drained naturally by the deepening of the beds of rivers. Deserted river-courses are not unfrequent, as that of the Serio Morto, which formerly fell into the Adda, in Lombardy; and the Po itself has often deviated from its course. Subsequently to the year 1390, it deserted part of the territory of Cremona, and invaded that of Parma; its old channel being still recognizable, and bearing the name of Po Morto. Bressello is one of the towns of which the site was formerly on the left of the Po, but which is now on

the right bank. There is also an old channel of the Po in the territory of Parma, called Po Vecchio, which was abandoned in the twelfth century, when a great number of towns were destroyed. There are records of parish-churches, as those of Vicobellignano, Agojolo, and Martignana, having been pulled down and afterwards rebuilt at a greater distance from the devouring stream. In the fifteenth century the main branch again resumed its deserted channel, and carried away a great island opposite Casalmaggiore. At the end of the same century it abandoned, a second time, the bed called "Po Vecchio," carrying away three streets of Casalmaggiore. The friars in the monastery de' Serviti took the alarm in 1471, demolished their buildings, and reconstructed them at Fontana, whither they had transported the materials. In like manner, the church of S. Rocco was demolished in 1511. In the seventeenth century also the Po shifted its course for a mile in the same district, causing great devastations.*

Artificial embankments of Italian rivers. — To check these and similar aberrations, a general system of embankment has been adopted; and the Po, Adige, and almost all their tributaries, are now confined between high artificial banks. The increased velocity acquired by streams thus closed in, enables them to convey a much larger portion of foreign matter to the sea; and, consequently, the deltas of the Po and Adige have gained far more rapidly on the Adriatic since the practice of embankment became almost universal. But, although more sediment is borne to the sea, part of the sand and mud, which in the

* Dell' Antico Corso de' Fiumi Po, Oglio, ed Adda, dell' Giovanni Romani. Milan, 1828.

natural state of things would be spread out by annual inundations over the plain, now subsides in the bottom of the river-channels, and their capacity being thereby diminished, it is necessary, in order to prevent inundations in the following spring, to extract matter from the bed, and to add it to the banks, of the river. Hence it happens that these streams now traverse the plain on the top of high mounds, like the waters of aqueducts, and at Ferrara the surface of the Po has become more elevated than the roofs of the houses.* The magnitude of these barriers is a subject of increasing expense and anxiety, it having been sometimes found necessary to give an additional height of nearly one foot to the banks of the Adige and Po in a single season.

The practice of embankment was adopted on some of the Italian rivers as early as the thirteenth century; and Dante, writing in the beginning of the fourteenth, describes, in the seventh circle of hell, a rivulet of tears separated from a burning sandy desert by embankments "like those which, between Ghent and Bruges, were raised against the ocean, or those which the Paduans had erected along the Brenta to defend their villas on the melting of the Alpine snows."

Quale i Fiamminghi tra Guzzante e Bruggia,
Temendo il fiotto che in ver lor s'avventa,
Fanno lo schermo, perchè il mar si fuggia,
E quale i Padovan lungo la Brenta,
Per difender lor ville e lor castelli,
Anzi che Chiarentana il caldo senta —

Inferno, Canto xv.

Basin of the Mississippi.—The hydrographical basin of the Mississippi displays, on the grandest scale, the

* Prony, see Cuvier, Disc. Prélim. p. 146.

action of running water on the surface of a vast continent. This magnificent river rises nearly in the forty-ninth parallel of north latitude, and flows to the Gulf of Mexico in the twenty-ninth — a course, including its meanders, of nearly five thousand miles. It passes from a cold arctic climate, traverses the temperate regions, and discharges its waters into the sea in the region of the olive, the fig, and the sugar-cane.* No river affords a more striking illustration of the law before mentioned, that an augmentation of volume does not occasion a proportional increase of surface, nay, is even sometimes attended with a narrowing of the channel. The Mississippi is half a mile wide at its junction with the Missouri †, the latter being also of equal width; yet the united waters have only, from their confluence to the mouth of the Ohio, a medial width of about three quarters of a mile. The junction of the Ohio seems also to produce no increase, but rather a decrease, of surface.‡ The St. Francis, White, Arkansas, and Red rivers, are also absorbed by the main stream with scarcely any apparent increase of its width; and, on arriving near the sea at New Orleans, it is somewhat less than half a mile wide. Its depth there is very variable, the greatest at high water being 168 feet. The mean rate at which the whole body of water flows is variously estimated. According to some, it does not exceed one mile an hour.§

* Flint's Geography, vol. i. p. 21.

† Flint says (vol. i. p. 140.) that, where the Mississippi receives the Missouri, it is a mile and a half wide, but, according to Captain B. Hall, this is a great mistake. — Travels in the United States, vol. iii. p. 328.

‡ Flint's Geography, vol. i. p. 142.

§ Hall's Travels in North America, vol. iii. p. 330., who cites Darby.

The alluvial plain of this great river is bounded on the east and west by great ranges of mountains stretching along their respective oceans. Below the junction of the Ohio, the plain is from thirty to fifty miles broad, and after that point it goes on increasing in width, till the expanse is perhaps three times as great! On the borders of this vast alluvial tract are perpendicular cliffs, or "bluffs," as they are called, sometimes three hundred feet or more in height, composed of limestone and other rocks, and often of alluvium. For a great distance the Mississippi washes the eastern "bluffs;" and below the mouth of the Ohio, never once comes in contact with the western. The waters are thrown to the eastern side, because all the large tributary rivers entering from the west, have filled that side of the great valley with a sloping mass of clay and sand. For this reason, the eastern bluffs are continually undermined, and the Mississippi is slowly but incessantly progressing eastward.*

Curves of the Mississippi. — The river traverses the plain in a meandering course, describing immense and uniform curves. After sweeping round the half of a circle, it is carried in a rapid current diagonally across its own channel, to another curve of the same uniformity upon the opposite shore.† These curves are so regular, that the boatmen and Indians calculate distances by them. Opposite to each of them there is always a sand-bar, answering, in the convexity of its form, to the concavity of "the bend," as it is called.‡ The river, by continually wearing these

* Geograph. Descrip. of the State of Louisiana, by W. Darby, Philadelphia, 1816, p. 102.

† Flint's Geog. vol. i. p. 152. ‡ Ibid.

curves deeper, returns, like many other streams before described, on its own tract, so that a vessel in some places, after sailing for twenty-five or thirty miles, is brought round again to within a mile of the place whence it started. When the waters approach so near to each other, it often happens at high floods that they burst through the small tongue of land, and insulate a portion, rushing through what is called the "cut off" with great velocity. At one spot, called the "grand cut off," vessels now pass from one point to another in half a mile to a distance which it formerly required a voyage of twenty miles to reach.*

Waste of its banks. — After the flood season, when the river subsides within its channel, it acts with destructive force upon the alluvial banks, softened and diluted by the recent overflow. Several acres at a time, thickly covered with wood, are precipitated into the stream; and large portions of the islands formed by the process before described are swept away.

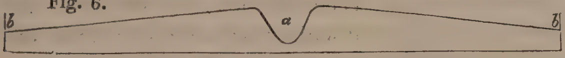
"Some years ago," observes Captain Hall, "when the Mississippi was regularly surveyed, all its islands were numbered, from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are entirely melted away — at other places they have attached themselves to the main shore, or, which is the more correct statement, the interval has been filled up by myriads of logs cemented together by mud and rubbish."† When the Mississippi and many

* Flint's Geog. vol. i. p. 154.

† Travels in North America, vol. iii. p. 361.

of its great tributaries overflow their banks, the waters, being no longer borne down by the main current, and becoming impeded amongst the trees and bushes, deposit the sediment of mud and sand with which they are abundantly charged. Islands arrest the progress of floating trees, and they often become in this manner reunited to the land; the rafts of trees, together with mud, constituting at length a solid mass. The coarser and more sandy portion is thrown down first nearest the banks; and finer particles are deposited at the farthest distances from the river, where an impalpable mixture subsides, forming a stiff unctuous black soil. Hence, in the alluvial plains of these rivers the land slopes back, like a natural glacis, towards the cliffs bounding the great valley (see fig. 6.), and during

Fig. 6.



a, Channel of the river. *b*, Base of the "bluffs."

inundations the highest part of the banks form narrow strips of dry ground, rising above the river on one side, and above the low flooded country on the other. The Mississippi therefore has been described as a river running on the top of a long hill or ridge, which has an elevation of twenty-four feet in its highest part, and a base three miles in average diameter. Flint, however, remarks, that this picture is not very correct, for, notwithstanding the comparative elevation of the banks, the deepest part of the bed of the river (*a*, fig. 6.) is uniformly lower than the lowest point of the alluvium at the base of the bluffs.*

It appears then that the Mississippi, by the continual

* Flint's Geography, vol. i. p. 151.

shifting of its course, sweeps away, during a great portion of the year, considerable tracts of alluvium which were gradually accumulated by the overflow of former years, and the matter now left during the spring-floods will be at some future time removed.

Raft of the Atchafalaya.—One of the most interesting features in this basin is "the raft." The dimensions of this mass of timber were given by Darby, in 1816, as ten miles in length, about 220 yards wide, and eight feet deep, the whole of which had accumulated, in consequence of some obstruction, during about thirty-eight years, in an arm of the Mississippi, called the Atchafalaya, which is supposed to have been at some past time a channel of the Red River before it intermingled its waters with the main stream. This arm is in a direct line with the general course of the Mississippi, and it catches a large portion of the drift wood annually brought down.

The mass of timber in the raft is continually increasing, and the whole rises and falls with the water. Although floating, it is covered with green bushes, like a tract of solid land, and its surface is enlivened in the autumn by a variety of beautiful flowers.

The rafts on Red River are equally remarkable; in some parts of its course, cedar trees are heaped up by themselves, and in other places pines. There is also a raft on the Washita, the principal tributary of the Red River, which seriously interrupts the navigation, concealing the whole river for seventeen leagues. This natural bridge is described in 1804 as supporting all the plants then growing in the neighbouring forest, not excepting large trees; and so perfectly was the stream concealed by the superincumbent mass, that it

might be crossed in some places without any knowledge of its existence.*

Drift Wood. — Notwithstanding the astonishing number of cubic feet of timber arrested by the rafts, great deposits are unceasingly in progress at the extremity of the delta in the Bay of Mexico. "Unfortunately for the navigation of the Mississippi," observes Captain Hall, "some of the largest trunks, after being cast down from the position on which they grew, get their roots entangled with the bottom of the river, where they remain anchored, as it were, in the mud. The force of the current naturally gives their tops a tendency downwards, and, by its flowing past, soon strips them of their leaves and branches. These fixtures, called snags or planters, are extremely dangerous to the steam-vessels proceeding up the stream, in which they lie like a lance in rest, concealed beneath the water, with their sharp ends pointed directly against the bow of the vessels coming up. For the most part, these formidable snags remain so still, that they can be detected only by a slight ripple above them, not perceptible to inexperienced eyes. Sometimes, however, they vibrate up and down, alternately showing their heads above the surface and bathing them beneath it."† So imminent is the danger caused by these obstructions, that almost all the boats on the Mississippi are constructed on a particular plan, to guard against fatal accidents.‡

* Navigator, p. 263. Pittsburgh, 1821.

† Travels in North America, vol. iii. p. 362.

‡ "The boats are fitted," says Captain Hall, "with what is called a snag-chamber;—a partition formed of stout planks, which is caulked, and made so effectually water-tight, that the foremost end of the vessel is cut off as entirely from the rest of the hold as

The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest, not merely as illustrating the manner in which abundance of vegetable matter becomes, in the ordinary course of Nature, imbedded in submarine and estuary deposits, but as attesting the constant destruction of soil and transportation of matter to lower levels by the tendency of rivers to shift their courses. Each of these trees must have required many years, some of them many centuries, to attain their full size; the soil, therefore, whereon they grew, after remaining undisturbed for long periods, is ultimately torn up and swept away. Yet, notwithstanding this incessant destruction of land and up-rooting of trees, the region which yields this never-failing supply of drift wood is densely clothed with noble forests, and is almost unrivalled in its power of supporting animal and vegetable life.

Innumerable herds of wild deer and bisons feed on the luxurious pastures of the plains. The jaguar, the wolf, and the fox, are amongst the beasts of prey. The waters teem with alligators and tortoises, and their surface is covered with millions of migratory water-fowl, which perform their annual voyage between the Canadian lakes and the shores of the Mexican Gulf. The power of man begins to be sensibly felt, and the wilderness to be replaced by towns, orchards, and gardens. The gilded steam-boat, like a moving city, now stems the current with a steady pace — now

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if it belonged to another boat. If the steam-vessel happen to run against a snag, and that a hole is made in her bow, under the surface, this chamber merely fills with water." Travels in North America, vol. iii. p. 363.

shoots rapidly down the descending stream through the solitudes of the forests and prairies. Already does the flourishing population of the great valley exceed that of the thirteen United States when first they declared their independence, and, after a sanguinary struggle, were severed from the parent country.* Such is the state of a continent where rocks and trees are hurried annually, by a thousand torrents, from the mountains to the plains, and where sand and finer matter are swept down by a vast current to the sea, together with the wreck of countless forests and the bones of animals which perish in the inundations. When these materials reach the Gulf, they do not render the waters unfit for aquatic animals; but, on the contrary, the ocean here swarms with life, as it generally does where the influx of a great river furnishes a copious supply of organic and mineral matter. Yet many geologists, when they behold the spoils of the land heaped in successive strata, and blended confusedly with the remains of fishes, or interspersed with broken shells and corals, imagine that they are viewing the signs of a turbulent instead of a tranquil and settled state of the planet. They read in such phenomena the proof of chaotic disorder, and reiterated catastrophes, instead of indications of a surface as habitable as the most delicious and fertile districts now tenanted by man. They are not content with disregarding the analogy of the present course of Nature, when they speculate on the revolutions of past times, but they often draw conclusions, concerning the former state of things, directly the reverse of those to which a fair induction from facts would infallibly lead them.

* Flint's Geography, vol. i.

Formation of lakes in Louisiana. — Another striking feature in the basin of the Mississippi, illustrative of the changes now in progress, is the formation by natural causes of great lakes, and the drainage of others. These are especially frequent in the basin of the Red River in Louisiana, where the largest of them, called Bistineau, is more than *thirty miles* long, and has a medium depth of from *fifteen* to *twenty* feet. In the deepest parts are seen numerous cypress-trees, of all sizes, now dead, and most of them with their tops broken by the wind, yet standing erect under water. This tree resists the action of air and water longer than any other, and, if not submerged throughout the whole year, will retain life for an extraordinary period.* Lake Bistineau, as well as Black Lake, Cado Lake, Spanish Lake, Natchitoches Lake, and many others, have been formed, according to Darby, by the gradual elevation of the bed of Red River, in which the alluvial accumulations have been so great as to raise its channel, and cause its waters, during the flood season, to flow up the mouths of many tributaries, and to convert parts of their courses into lakes. In the autumn, when the level of Red River is again depressed, the waters rush back again, and some lakes become grassy meadows, with streams meandering through them.† Thus, there is a periodical flux and reflux between Red River and some of these basins, which are merely reservoirs, alternately emptied and

* Captains Clark and Lewis found a forest of pines standing erect under water in the body of the Columbia River in North America, which, they supposed, from the appearance of the trees, to have been submerged only about twenty years. — Vol. ii. p. 241.

† Darby's Louisiana, p. 33.

filled like our tide estuaries — with this difference, that in the one case the land is submerged for several months continuously, and, in the other, twice in every twenty-four hours. It has happened, in several cases, that a bar has been thrown by Red River across some of the openings of these channels, and then the lakes become, like Bistineau, constant repositories of water. But even in these cases, their level is liable to annual elevation and depression, because the flood of the main river, when at its height, passes over the bar; just as, where sand-hills close the entrance of an estuary on the Norfolk or Suffolk coast, the sea, during some high tide or storm, has often breached the barrier and inundated again the interior.

Earthquakes in basin of Mississippi. — The frequent fluctuations in river courses, in various parts of the basin of the Mississippi, are partly, perhaps, to be ascribed to the co-operation of subterranean movements, which alter from time to time the relative levels of various parts of the surface. So late as the year 1812, the whole valley from the mouth of the Ohio to that of the St. Francis, including a tract three hundred miles in length, and exceeding in area the whole basin of the Thames, was convulsed to such a degree, as to create new islands in the river, and lakes in the alluvial plain, some of which were *twenty miles in extent*. I shall allude to this event, by which New Madrid was in great part destroyed, when I treat of earthquakes; but may state here, that it happened exactly at the same time as the fatal convulsions in the district of Caraccas; and the country shaken was nearly five degrees of latitude farther removed from the great centre of volcanic disturbance, than the basin of the Red River before alluded to. Darby

mentions beds of marine shells on the banks of Red River, which seem to indicate that Lower Louisiana is of recent formation: its elevation, perhaps, above the sea, may have been due to the same series of earthquakes which continues to agitate equatorial America.

When countries are liable to be so extensively and permanently affected by earthquakes, speculations concerning changes in their hydrographical features must not be made without regard to the igneous as well as the aqueous causes of change. It is scarcely necessary to observe, that the inequalities produced even by one shock might render the study of the alluvial plain of the Mississippi, at some future period, most perplexing to a geologist who should reason on the distribution of transported materials, without being aware that the configuration of the country had varied materially during the time when the excavating or removing power of the river was greatest.

FLOODS, BURSTING OF LAKES, ETC.

The power which running water may exert, in the lapse of ages, in widening and deepening a valley, does not so much depend on the volume and velocity of the stream usually flowing in it, as on the number and magnitude of the obstructions which have, at different periods, opposed its free passage. If a torrent, however small, be effectually dammed up, the size of the valley above the barrier, and its declivity below, and not the dimensions of the torrent, will determine the violence of the débâcle. The most universal source of local deluges are land-slips, slides, or avalanches, as they are sometimes called, when great masses of rock

and soil, or sometimes ice and snow, are precipitated into the bed of a river, the boundary cliffs of which have been thrown down by the shock of an earthquake, or undermined by springs or other causes. Volumes might be filled with the enumeration of instances on record of these terrific catastrophes: I shall therefore select a few examples of very recent occurrence, the facts of which are well authenticated.

Floods caused by land-slips, 1826.—Two dry seasons in the White Mountains, in New Hampshire, were followed by heavy rains on the 28th August, 1826, when from the steep and lofty declivities which rise abruptly on both sides of the river Saco innumerable rocks and stones, many of sufficient size to fill a common apartment, were detached, and in their descent swept down before them, in one promiscuous and frightful ruin, forests, shrubs, and the earth which sustained them. No tradition existed of any similar slides at former times, and the growth of the forest on the flanks of the hills clearly showed that for a long interval nothing similar had occurred. One of these moving masses was afterwards found to have slid three miles, with an average breadth of a quarter of a mile. The natural excavations commenced generally in a trench a few yards in depth and a few rods in width, and descended the mountains, widening and deepening till they became vast chasms. At the base of these hollow ravines was seen a wide and deep mass of ruins, consisting of transported earth, gravel, rocks, and trees. Forests of spruce-fir and hemlock were prostrated with as much ease as if they had been fields of grain; for, where they disputed the ground, the torrent of mud and rock accumulated behind till it gathered sufficient force to burst the temporary barrier.

The valleys of the Amonoosuck and Saco presented, for many miles, an uninterrupted scene of desolation; all the bridges being carried away, as well as those over their tributary streams. In some places, the road was excavated to the depth of from fifteen to twenty feet; in others, it was covered with earth, rocks, and trees, to as great a height. The water flowed for many weeks after the flood, as densely charged with earth as it could be without being changed into mud, and marks were seen in various localities of its having risen on either side of the valley to more than twenty-five feet above its ordinary level. Many sheep and cattle were swept away, and the Willey family, nine in number, who in alarm had deserted their house, were destroyed on the banks of the Saco; seven of their mangled bodies were afterwards found near the river, buried beneath drift wood and mountain ruins.* The geologist should remark that the lower alluvial plains are most exposed to such violent floods, and at the same time are best fitted for the sustenance of herbivorous animals. If, therefore, any organic remains are found amidst the superficial heaps of transported matter, resulting from those catastrophes, at whatever periods they may have happened, and whatever may have been the former configuration and relative levels of the country, we may expect the imbedded fossil relics to be principally referrible to this class of mammalia.

But these catastrophes are insignificant, when compared to those which are occasioned by earthquakes, when the boundary hills, for miles in length, are

* Silliman's Journal of Science, vol. xv. No. 2. p. 216. Jan. 1829.

thrown down into the hollow of a valley. I shall have opportunities of alluding to inundations of this kind when treating expressly of earthquakes, and shall content myself at present with selecting an example, of modern date, of a flood caused by the bursting of a temporary lake; the facts having been described, with with more than usual accuracy, by scientific observers.

Flood in the Valley of Bagnes, 1818.—The valley of Bagnes is one of the largest of the lateral embranchments of the main valley of the Rhone, above the Lake of Geneva. Its upper portion was, in 1818, converted into a lake by the damming up of a narrow pass, by avalanches of snow and ice, precipitated from an elevated glacier into the bed of the river Dranse. In the winter season, during continued frost, scarcely any water flows in the bed of this river to preserve an open channel, so that the ice-barrier remained entire until the melting of the snows in spring, when a lake was formed above, about half a league in length, which finally attained in some parts a depth of about two hundred feet, and a width of about seven hundred feet. To prevent or lessen the mischief apprehended from the sudden bursting of the barrier, an artificial gallery, seven hundred feet in length, was cut through the ice, before the waters had risen to a great height. When at length they accumulated and flowed through this tunnel, they dissolved the ice, and thus deepened their channel, until nearly half of the whole contents of the lake were slowly drained off. But, at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of its descent, the waters encountered

several narrow gorges, and at each of these they rose to a great height, and then burst with new violence into the next basin, sweeping along rocks, forests, houses, bridges, and cultivated land. For the greater part of its course the flood resembled a moving mass of rock and mud, rather than of water. Some fragments of granitic rocks, of enormous magnitude, and which, from their dimensions, might be compared without exaggeration to houses, were torn out of a more ancient alluvion, and borne down for a quarter of a mile. One of the fragments moved was sixty paces in circumference.* The velocity of the water, in the first part of its course, was thirty-three feet per second, which diminished to six feet before it reached the Lake of Geneva, where it arrived in six hours and a half, the distance being forty-five miles.†

This flood left behind it, on the plains of Martigny, thousands of trees torn up by the roots, together with the ruins of buildings. Some of the houses in that town were filled with mud up to the second story. After expanding in the plain of Martigny, it entered the Rhone and did no further damage; but some bodies of men, who had been drowned above Martigny, were afterwards found, at the distance of about thirty miles, floating on the farther side of the Lake of Geneva, near Vevey.

The waters, on escaping from the temporary lake, intermixed with mud and rock, swept along, for the first four miles, at the rate of above twenty miles an hour;

* This block was measured by Capt. B. Hall, R. N.

† See an account of the inundation of the Val de Bagnes, in 1818, in Ed. Phil. Journ., vol. i. p. 187., drawn up from the Memoir of M. Escher, with a section, &c.

and M. Escher, the engineer, calculated that the flood furnished 300,000 cubic feet of water every second — an efflux which is five times greater than that of the Rhine below Basle. Now, if part of the lake had not been gradually drained off, the flood would have been nearly double, approaching in volume to some of the largest rivers in Europe. It is evident, therefore, that, when we are speculating on the excavating force which a river may have exerted in any particular valley, the most important question is, not the volume of the existing stream, nor the present levels of its channel, nor even the nature of the rocks, but the probability of a succession of floods, at some period since the time when the valley may have been first elevated above the sea.

For several months after the débâcle of 1818, the Dranse, having no settled channel, shifted its position continually from one side to the other of the valley, carrying away newly erected bridges, undermining houses, and continuing to be charged with as large a quantity of earthy matter as the fluid could hold in suspension. I visited this valley four months after the flood, and was witness to the sweeping away of a bridge, and the undermining of part of a house. The greater part of the ice-barrier was then standing, presenting vertical cliffs 150 feet high, like ravines in the lava-currents of Etna or Auvergne, where they are intersected by rivers.

Inundations, precisely similar, are recorded to have occurred at former periods in this district, and from the same cause. In 1595, for example, a lake burst, and the waters, descending with irresistible fury, destroyed the town of Martigny, where from sixty to

eighty persons perished. In a similar flood, fifty years before, 140 persons were drowned.

Flood at Tivoli, 1826. — I shall conclude with one more example, derived from a land of classic recollections, the ancient Tibur, and which, like all the other inundations above alluded to, occurred within the present century. The younger Pliny, it will be remembered, describes a flood on the Anio, which destroyed woods, rocks, and houses, with the most sumptuous villas and works of art.* For four or five centuries consecutively, this "headlong stream," as Horace truly called it, has often remained within its bounds, and then, after so long an interval of rest, has at different periods inundated its banks again, and widened its channel. The last of these catastrophes happened 15th Nov. 1826, after heavy rains, such as produced the floods before alluded to in Scotland. The waters appear also to have been impeded by an artificial dike, by which they were separated into two parts, a short distance above Tivoli. They broke through this dike; and, leaving the left trench dry, precipitated themselves, with their whole weight, on the right side. Here they undermined, in the course of a few hours, a high cliff, and widened the river's channel about fifteen paces. On this height stood the church of St. Lucia, and about thirty-six houses of the town of Tivoli, which were all carried away, presenting, as they sank into the roaring flood, a terrific scene of destruction to the spectators on the opposite bank. As the foundations were gradually removed, each building, some of them edifices of considerable height,

* Lib. viii. Epist. 17.

was first traversed with numerous rents, which soon widened into large fissures, until at length the roofs fell in with a crash, and then the walls sank into the river, and were hurled down the cataract below.*

The destroying agency of the flood came within two hundred yards of the precipice on which the beautiful temple of Vesta stands; but fortunately this precious relic of antiquity was spared, while the wreck of modern structures was hurled down the abyss. Vesta, it will be remembered, in the heathen mythology, personified the stability of the earth; and when the Samian astronomer, Aristarchus, first taught that the earth revolved on its axis, and round the sun, he was publicly accused of impiety, "for moving the everlasting Vesta from her place." Playfair observed, that when Hutton ascribed instability to the earth's surface, and represented the continents which we inhabit as the theatre of incessant change and movement, his antagonists, who regarded them as unalterable, assailed him, in a similar manner, with accusations founded on religious prejudices.† We might appeal to the excavating power of the Anio as corroborative of one of the most controverted parts of the Huttonian theory; and, if the days of omens had not gone by, the geologists who now worship Vesta might regard the late catastrophe as portentous. We may, at least, recommend the modern votaries of the goddess to lose no time in making a pilgrimage to her shrine, for the next flood may not respect the temple.

* When at Tivoli, in 1829, I received this account from eye-witnesses of the event.

† Illustr. of Hutt. Theory, § 3. p. 147.

CHAPTER III.

PHENOMENA OF SPRINGS.

Origin of Springs — Bored wells — Distinct causes by which mineral and thermal waters may be raised to the surface — Their connection with volcanic agency (p. 304.) — Calcareous Springs — Travertin of the Elsa — Baths of San Vignone and of San Filippo, near Radicofani — Spheroidal structure in travertin, as in English magnesian limestone (p. 313.) — Bulicami of Viterbo — Lake of the Solfatara, near Rome — Travertin at Cascade of Tivoli (p.318.) — Gypseous, Siliceous, and Ferruginous Springs — Brine Springs (p. 326.) — Carbonated Springs — Disintegration of granite in Auvergne — Petroleum Springs — Pitch Lake of Trinidad.

Origin of springs. — The action of running water on the land having been considered, we may next turn our attention to what may be termed "the subterranean drainage," or the phenomena of springs. Every one is familiar with the fact, that certain porous soils, such as loose sand and gravel, absorb water with rapidity; and that the ground composed of them soon dries up after heavy showers. If a well be sunk in such soils, we often penetrate to considerable depths before we meet with water; but this is usually found on our approaching the lower parts of the formation, where it rests on some impervious bed; for here the water, unable to make its way downwards in a direct line, accumulates as in a reservoir, and is ready to ooze out into any opening which may be made, in the same manner as we see the salt water flow into, and fill,

any hollow which we dig in the sands of the shore at low tide.

The facility with which water can percolate loose and gravelly soils is clearly illustrated by the effect of the tides in the Thames between Richmond and London. The river, in this part of its course, flows through a bed of gravel overlying clay, and the porous superstratum is alternately saturated by the water of the Thames as the tide rises, and then drained again to the distance of several hundred feet from the banks when the tide falls, so that the wells in this tract regularly ebb and flow.

If the transmission of water through a porous medium be so rapid, we cannot be surprised that springs should be thrown out on the side of a hill, where the upper set of strata consist of chalk, sand, or other permeable substances, while the subjacent are composed of clay or other retentive soils. The only difficulty, indeed, is, to explain, why the water does not ooze out every where along the line of junction of the two formations, so as to form one continuous land-soak, instead of a few springs only, and these far distant from each other. The principal cause of this concentration of the waters at a few points is, first, the frequency of rents and fissures, which act as natural drains; secondly, the existence of inequalities in the upper surface of the impermeable stratum, which lead the water, as valleys do on the external surface of a country, into certain low levels and channels.

That the generality of springs owe their supply to the atmosphere is evident from this, that they become languid, or entirely cease to flow, after long droughts, and are again replenished after a continuance of rain. Many of them are probably indebted for the constancy

and uniformity of their volume to the great extent of the subterranean reservoirs with which they communicate, and the time required for these to empty themselves by percolation. Such a gradual and regulated discharge is exhibited, though in a less perfect degree, in every great lake, which is not sensibly affected in its level by sudden showers, but only slightly raised; so that its channel of efflux, instead of being swoln suddenly like the bed of a torrent, is enabled to carry off the surplus water gradually.

Much light has been thrown, of late years, on the theory of springs, by the boring of what are called by the French "Artesian wells," because the method has long been known and practised in Artois; and it is now demonstrated that there are sheets, and, in some places, currents of fresh water, at various depths in the earth. The instrument employed in excavating these wells is a large auger, and the cavity bored is usually from three to four inches in diameter. If a hard rock is met with, it is first triturated by an iron rod, and the materials, being thus reduced to small fragments or powder, are readily extracted. To hinder the sides of the well from falling in, as also to prevent the spreading of the ascending water in the surrounding soil, a jointed pipe is introduced, formed of wood in Artois, but in other countries more commonly of metal. It frequently happens that, after passing through hundreds of feet of retentive soils, a water-bearing stratum is at length pierced, when the fluid immediately ascends to the surface and flows over. The first rush of the water up the tube is often violent, so that for a time the water plays like a fountain, and then, sinking, continues to flow over tranquilly, or sometimes remains stationary at a certain depth below the orifice of the well.

This spouting of the water in the first instance is probably owing to the disengagement of air and carbonic acid gas, for both of these have been seen to bubble up with the water.*

At Sheerness, at the mouth of the Thames, a well was bored on a low tongue of land near the sea, through 300 feet of the blue clay of London, below which a bed of sand and pebbles was entered, belonging, doubtless to the plastic clay formation: when this stratum was pierced, the water burst up with impetuosity, and filled the well. By another perforation at the same place, the water was found at the depth of 328 feet, below the surface clay; it first rose rapidly to the height of 189 feet, and then, in the course of a few hours, ascended to an elevation of eight feet above the level of the ground. In 1824, a well was dug at Fulham, near the Thames, at the Bishop of London's, to the depth of 317 feet, which, after traversing the tertiary strata, was continued through 67 feet of chalk. The water immediately rose to the surface, and the discharge was above 50 gallons per minute. In the garden of the Horticultural Society at Chiswick, the borings passed through 19 feet of gravel, 242 feet of clay and loam, and 67 feet of chalk, and the water then rose to the surface from a depth of 329 feet. † At the Duke of Northumberland's, above Chiswick, the borings were carried to the extraordinary depth of 620 feet, so as to enter the chalk, when a considerable volume of water was obtained, which rose four feet above the surface of the ground. In a well of Mr. Brooks, at Hammersmith, the rush of water from a depth of 360

* Consult Héricart de Thury's work on "Puits Forés."

† Sabine, Journ. of Sci., No. 33. p. 72, 1824.

feet was so great, as to inundate several buildings and do considerable damage; and at Tooting, a sufficient stream was obtained to turn a wheel, and raise the water to the upper stories of the houses.* In the last of three wells bored through the chalk, at Tours, to the depth of several hundred feet, the water rose thirty-two feet above the level of the soil, and the discharge amounted to three hundred cubic yards of water every twenty-four hours. †

Excavations have been made in the same way to the depth of eight hundred, and even twelve hundred feet in France (the latter at Toulouse), and without success. ‡ A similar failure was experienced in 1830, in boring at Calcutta, to the depth of more than 150 feet, through the alluvial clay and sands of Bengal. Mr. Briggs, the British consul in Egypt, obtained water between Cairo and Suez, in a calcareous sand, at the depth of thirty feet; but it did not rise in the well.§ The geological structure of the Sahara is supposed, by M. Rozet, to favour the prospect of a supply of water from artesian wells, as the parched sands on the outskirts of the desert rest on a substratum of argillaceous marl.||

The rise and overflow of the water in these wells is generally referred, and apparently with reason, to the same principle as the play of an artificial fountain. Let the porous stratum, or set of strata *a a*, rest on the impermeable rock *d*, and be covered by another mass of an impermeable nature. The whole mass *a a* may easily, in such a position, become saturated with

* Héricart de Thury, p. 49.

† Bull. de la Soc. Géol. de France, tom. iii. p. 194.

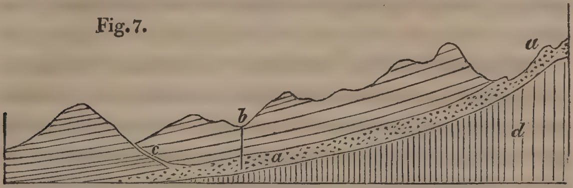
‡ Id. tom. ii. p. 272.

§ Boué, Résumé des Prog. de la Géol. en 1832, p. 184.

|| Bull. de la Soc. Géol. de France, tom. ii. p. 364.

water, which may descend from its higher and exposed parts—a hilly region to which clouds are attracted,

Fig. 7.



and where rain falls in abundance. Suppose that at some point, as at *b*, an opening be made which gives a free passage upwards to the waters confined in *a a* at so low a level that they are subjected to the pressure of a considerable column of water collected in the more elevated portion of the same stratum. The water will then rush out, just as the liquid from a large barrel which is tapped, and it will rise to a height corresponding to the level of its point of departure, or, rather, to a height, which balances the pressure previously exerted by the confined waters against the roof and sides of the stratum or reservoir *a a*. In like manner, if there happen to be a natural fissure *c*, a spring will be produced at the surface on precisely the same principle.

Among the causes of the failure of artesian wells, we may mention those numerous rents and faults which abound in some rocks, and the deep ravines and valleys by which many countries are traversed; for, when these natural lines of drainage exist, there remains a small quantity only of water to escape by artificial issues. We are also liable to be baffled by the great thickness either of porous or impervious strata, or by the dip of the beds, which may carry off the waters from adjoining high lands, to some trough in an

opposite direction; as when the borings are made at the foot of an escarpment where the strata incline inwards, or in a direction opposite to the face of the cliffs.

The mere distance of hills or mountains need not discourage us from making trials; for the waters which fall on these higher lands readily penetrate to great depths through highly inclined or vertical strata, or through the fissures of shattered rocks, and after flowing for a great distance, must often re-ascend and be brought up again by other fissures, so as to approach the surface in the lower country. Here they may be concealed beneath a covering of undisturbed horizontal beds, which it may be necessary to pierce in order to reach them. It should be remembered, that the course of waters flowing under ground bears but a remote resemblance to that of rivers on the surface, there being, in the one case, a constant descent from a higher to a lower level from the source of the stream to the sea; whereas, in the other, the water may at one time sink far below the level of the ocean, and afterwards rise again high above it.

Among other curious facts ascertained by aid of the borer, it is proved that in strata of different ages and compositions there are often open passages by which the subterranean waters circulate. Thus, at St. Ouen, in France, five distinct sheets of water were intersected in a well, and from each of these a supply obtained. In the third water-bearing stratum, at the depth of 150 feet, a cavity was found in which the borer fell suddenly about a foot, and thence the water ascended in great volume.* The same falling of

* H. de Thury, p. 295.

the instrument, as in a hollow space, has been remarked in England and other countries. At Tours, in 1830, a well was perforated quite through the chalk, when the water suddenly brought up, from a depth of 364 feet, a great quantity of fine sand, with much vegetable matter and shells. Branches of a thorn several inches long, much blackened by their stay in the water, were recognized, as also the stems of marsh plants, and some of their roots, which were still white, together with the seeds of the same, in a state of preservation which showed that they had not remained more than three or four months in the water. Among the seeds were those of the marsh-plant *Galium uliginosum*; and among the shells, a freshwater species (*Planorbis marginatus*), and some land species, as *Helix rotundata* and *H. striata*. M. Dujardin, who, with others, observed this phenomenon, supposes that the waters had flowed from some valleys of Auvergne or the Vivarais since the preceding autumn.*

An analogous phenomenon is recorded at Riemke, near Bochum in Westphalia, where the water of an artesian well brought up, from a depth of 156 feet, several small fish, three or four inches long, the nearest streams in the country being at the distance of some leagues.†

In both cases it is evident that water had penetrated to great depths, not simply by filtering through a porous mass, for then it would have left behind the shells, fish, and fragments of plants, but by flowing through some open channels in the earth. Such examples may suggest the idea that the leaky beds of rivers are often the feeders of springs.

* Bull. de la Soc. Géol. de France, tom. i. p. 95.

† Id. p. 248.

MINERAL AND THERMAL SPRINGS.

Almost all springs, even those which we consider the purest, are impregnated with some foreign ingredients, which, being in a state of chemical solution, are so intimately blended with the water, as not to affect its clearness, while they render it, in general, more agreeable to our taste, and more nutritious than simple rain-water. But the springs called mineral contain an unusual abundance of earthy matter in solution, and the substances with which they are impregnated correspond remarkably with those evolved in a gaseous form by volcanos. Many of these springs are thermal, and they rise up through all kinds of rock; as, for example, through granite, gneiss, limestone, or lava, but are most frequent in volcanic regions, or where violent earthquakes have occurred at eras comparatively modern.

The water given out by hot springs is generally more voluminous and less variable in quantity at different seasons than that proceeding from any others. In many volcanic regions, jets of steam, called by the Italians "stufas," issue from fissures, at a temperature high above the boiling point, as in the neighbourhood of Naples, and in the Lipari Isles, and are disengaged unceasingly for ages. Now, if such columns of steam, which are often mixed with other gases, should be condensed before reaching the surface, by coming in contact with strata filled with cold water, they may give rise to thermal and mineral springs of every degree of temperature. It is, indeed, by this means only, and not by hydrostatic pressure, that we can account for the rise of such bodies of water from great depths; nor can we hesitate to admit the adequacy of

the cause, if we suppose the expansion of the same elastic fluids to be sufficient to raise columns of lava to the lofty summits of volcanic mountains. Several gases, the carbonic acid in particular, are disengaged in a free state from the soil in many districts, especially in the regions of active or extinct volcanos; and the same are found more or less intimately combined with the waters of all mineral springs, both cold and thermal. Dr. Daubeny and other writers have remarked, not only that these springs are most abundant in volcanic regions, but that when remote from them, their site usually coincides with the position of some great derangement in the strata; a fault, for example, or great fissure, indicating that a channel of communication has been opened with the interior of the earth at some former period of local convulsion.

The small area of volcanic regions may appear, at first view, an objection to this theory, but not so when we include earthquakes among the effects of igneous agency. A large proportion of the land hitherto explored by geologists can be shown to have been rent or shaken by subterranean movements since the oldest tertiary strata were formed. It will also be seen, in the sequel, that new springs have burst out, and others have had the volume of their waters augmented, and their temperature suddenly raised after earthquakes; so that the description of these springs might almost with equal propriety have been given under the head of "igneous causes," as they are agents of a mixed nature, being at once igneous and aqueous.

But how, it will be asked, can the regions of volcanic heat send forth such inexhaustible supplies of water? The difficulty of solving this problem would, in truth,

be insurmountable, if we believed that all the atmospheric waters found their way into the basin of the ocean; but in boring near the shore, we often meet with streams of fresh water at the depth of several hundred feet below the sea level; and these probably descend, in many cases, far beneath the bottom of the sea, when not artificially intercepted in their course. Yet, how much greater may be the quantity of salt water which sinks beneath the floor of the ocean, through the porous strata of which it is often composed, or through fissures rent in it by earthquakes! After penetrating to a considerable depth, this water may encounter a heat of sufficient intensity to convert it into vapour, even under the high pressure to which it would then be subjected. This heat would probably be nearest the surface in volcanic countries, and farthest from it in those districts which have been longest free from eruptions or earthquakes: but to pursue this inquiry farther would lead us to anticipate many topics belonging to another division of our subject.

It would follow from the views above explained, that there must be a two-fold circulation of terrestrial waters; one caused by solar heat, and the other by heat generated in the interior of our planet. We know that the land would be unfit for vegetation, if deprived of the waters raised into the atmosphere by the sun; but it is also true that mineral springs are powerful instruments in rendering the surface subservient to the support of animal and vegetable life. Their heat is said to promote the development of the aquatic tribes in many parts of the ocean, and the substances which they carry up from the bowels of the

earth to the habitable surface, are of a nature and in a form which adapts them peculiarly for the nutrition of animals and plants.

As these springs derive their chief importance to the geologist from the quantity and quality of the earthy materials which, like volcanos, they convey from below upwards, they may properly be considered in reference to the ingredients with which they are impregnated. These consist of almost all known substances; but the most predominant are, carbonate of lime, carbonic and sulphuric acids, iron, silica, magnesia, alumine, and salt, besides petroleum, or liquid bitumen, and its various modifications, such as mineral pitch, naptha, and asphaltum.

Calcareous springs.—Our first attention is naturally directed to springs which are highly charged with calcareous matter; for these produce a variety of phenomena of much interest in geology. It is known that rain-water has the property of dissolving the calcareous rocks over which it flows, and thus in the smallest ponds and rivulets, matter is often supplied for the earthy secretions of testacea, and for the growth of certain plants on which they feed. But many springs hold so much carbonic acid in solution, that they are enabled to dissolve a much larger quantity of calcareous matter than rain-water; and when the acid is dissipated in the atmosphere, the mineral ingredients are thrown down, in the form of tufa or travertin.*

Auvergne.—Calcareous springs, although most abundant in limestone districts, are by no means confined

* The more loose and porous rock, usually containing incrusted plants and other substances, is called tufa, the more compact, travertin. See Glossary, articles Tufa and Travertin.

to them, but flow out indiscriminately from all rock formations. In Central France, a district where the primary rocks are unusually destitute of limestone, springs copiously charged with carbonate of lime rise up through the granite and gneiss. Some of these are thermal, and probably derive their origin from the deep source of volcanic heat, once so active in that region. One of these springs, at the northern base of the hill upon which Clermont is built, issues from volcanic peperino, which rests on granite. It has formed, by its incrustations, an elevated mound of travertin, or white concretionary limestone, 240 feet in length, and, at its termination, sixteen feet high and twelve wide. Another incrusting spring in the same department, situated at Chaluzet, near Pont Gibaud, rises in a gneiss country, at the foot of a regular volcanic cone, at least twenty miles from any calcareous rock. Some masses of tufaceous deposit, produced by this spring, have an oolitic texture.

Valley of the Elsa.—If we pass from the volcanic district of France to that which skirts the Apennines in the Italian peninsula, we meet with innumerable springs, which have precipitated so much calcareous matter, that the whole ground in some parts of Tuscany is coated over with travertin, and sounds hollow beneath the foot.

In other places in the same country, compact rocks are seen descending the slanting sides of hills, very much in the manner of lava currents, except that they are of a white colour, and terminate abruptly when they reach the course of a river. These consist of the calcareous precipitate of springs, some of them still flowing, while others have disappeared or changed their position. Such masses are frequent on the slope

of the hills which bound the valley of the Elsa, one of the tributaries of the Arno, which flows near Colle, through a valley several hundred feet deep, shaped out of a lacustrine formation, containing fossil shells of existing species. The travertin is unconformable to the lacustrine beds, and its inclination accords with the slope of the sides of the valley.

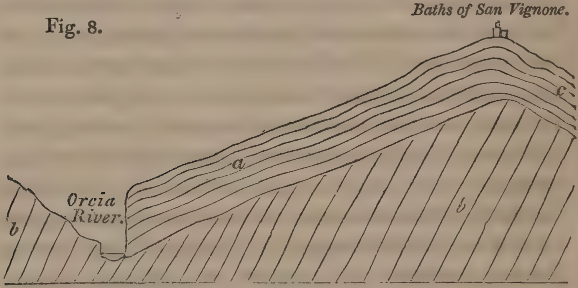
One of the finest examples which I saw, was at the Molino delle Caldane, near Colle.

The Sena, and several other small rivulets which feed the Elsa, have the property of lapidifying wood and herbs; and, in the bed of the Elsa itself, aquatic plants, such as Charæ, which absorb large quantities of carbonate of lime, are very abundant. Carbonic acid is also seen in the same valley, bubbling up from many springs, where no precipitate of tufa is observable. Targioni, who in his travels has mentioned a great number of mineral waters in Tuscany, found no difference between the deposits of cold and thermal springs. They issue sometimes from the older Apennine limestone, shale, and sandstone, while, in other places, they flow from more modern deposits; but even in the latter case, their source may probably be in or below the older series of strata.

Baths of San Vignone. — Those persons who have merely seen the action of petrifying waters in our own country, will not easily form an adequate conception of the scale on which the same process is exhibited in those regions which lie nearer to the active centres of volcanic disturbance. One of the most striking examples of the rapid precipitation of carbonate of lime from thermal waters occurs in the hill of San Vignone in Tuscany, at a short distance from Radicofani, and only a few hundred yards from the high

road between Sienna and Rome. The spring issues from near the summit of a rocky hill, about 100 feet in height. The top of the hill is flat, and stretches in a gently inclined platform to the foot of Mount Amiata, a lofty eminence, which consists in great part of volcanic products. The fundamental rock, from which the spring issues, is a black slate, with serpentine (*b b*, Fig. 8.), belonging to the older Apennine formation. The water is hot, has a strong taste, and,

Fig. 8.



Section of Travertin, San Vignone.

when not in very small quantity, is of a bright green colour. So rapid is the deposition near the source, that in the bottom of a conduit-pipe for carrying off the water to the baths, and which is inclined at an angle of 30°, half a foot of solid travertin is formed every year. A more compact rock is produced where the water flows slowly, and the precipitation in winter, when there is least evaporation, is said to be more solid, but less in quantity by one fourth, than in summer. The rock is generally white; some parts of it are compact, and ring to the hammer; others are cellular, and with such cavities as are seen in the carious part of bone or the siliceous millstone of the Paris basin. A portion of it also below the village of

San Vignone consists of incrustations of long vegetable tubes, and may be called tufa. Sometimes the travertin assumes precisely the botryoidal and mammillary forms, common to similar deposits in Auvergne, of a much older date, hereafter to be mentioned; and, like them, it often scales off in thin, slightly undulating layers.

A large mass of travertin (*c*, Fig. 8.) descends the hill from the point where the spring issues, and reaches to the distance of about half a mile east of San Vignone. The beds take the slope of the hill at about an angle of 6°, and the planes of stratification are perfectly parallel. One stratum, composed of many layers, is of a compact nature, and fifteen feet thick; it serves as an excellent building stone, and a mass of fifteen feet in length was, in 1828, cut out for the new bridge over the Orcia. Another branch of it (*a*, Fig. 8.) descends to the west, for 250 feet in length, of varying thickness, but sometimes 200 feet deep: it is then cut off by the small river Orcia, precisely as some glaciers in Switzerland descend into a valley till their progress is suddenly arrested by a transverse stream of water.

The abrupt termination of the mass of rock at the river, when its thickness is undiminished, clearly shows that it would proceed much farther if not arrested by the stream, over which it impends slightly. But it cannot encroach upon the channel of the Orcia being constantly undermined, so that its solid fragments are seen strewed amongst the alluvial gravel. However enormous, therefore, the mass of solid rock may appear which has been given out by this single spring, we may feel assured that it is insignificant in volume when compared to that which has been carried to the sea since the time when it began to flow. What may have been the length of that period of time, we have

no data for conjecturing. In quarrying the travertin, Roman tiles have been sometimes found at the depth of five or six feet.

Baths of San Filippo. — On another hill, not many miles from that last mentioned, and also connected with Mount Amiata, the summit of which is about three miles distant, are the celebrated baths of San Filippo. The subjacent rocks consist of alternations of black slate, limestone, and serpentine, of highly inclined strata, belonging to the Apennine formation, and, as at San Vignone, near the boundary of a tertiary basin of marine origin, consisting chiefly of blue argillaceous marl. There are three warm springs here, containing carbonate and sulphate of lime, and sulphate of magnesia. The water which supplies the bath falls into a pond, where it has been known to deposit a solid mass *thirty feet thick*, in about *twenty years*.* A manufactory of medallions in basso-relievo is carried on at these baths. The water is conducted by canals into several pits, in which it deposits travertin and crystals of sulphate of lime. After being thus freed from its grosser parts, it is conveyed by a tube to the summit of a small chamber, and made to fall through a space of ten or twelve feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds, which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould.† The geologist may

* Dr. Grosse on the Baths of San Filippo. Ed. Phil. Journ. vol. ii. p. 292.

† Id. p. 297.

derive from these experiments considerable light, in regard to the high inclination at which some semi-crystalline precipitations can be formed; for some of the moulds are disposed almost perpendicularly, yet the deposition is nearly equal in all parts.

A hard stratum of stone, about a foot in thickness, is obtained from the waters of San Filippo in four months; and, as the springs are powerful, and almost uniform in the quantity given out, we are at no loss to comprehend the magnitude of the mass which descends the hill, which is a mile and a quarter in length and the third of a mile in breadth, in some places attaining a thickness of 250 feet at least. To what length it might have reached it is impossible to conjecture, as it is cut off, like the travertin of San Vignone, by a small stream, where it terminates abruptly. The remainder of the matter held in solution is carried on probably to the sea.

Spheroidal structure in travertin.—But what renders this recent limestone of peculiar interest to the geologist, is the spheroidal form which it assumes, analogous to that of the cascade of Tivoli, afterwards to be described. The lamination of some of the concentric masses is so minute that sixty may be counted in the thickness of an inch, yet, notwithstanding these marks of gradual and successive deposition, sections are sometimes exhibited of what might seem to be perfect spheres. This tendency to a mammillary and globular structure arises from the facility with which the calcareous matter is precipitated in nearly equal quantities on all sides of any fragment of shell or wood, or any inequality of the surface over which the mineral water flows, the form of the nucleus being readily transmitted through any number of successive enve-

lopes. But these masses can never be perfect spheres, although they often appear such when a transverse section is made in any line not in the direction of the point of attachment. There are, indeed, occasionally seen small oolitic and pisolitic grains, of which the form is globular; for the nucleus, having been for a time in motion in the water, has received fresh accessions of matter on all sides.

In the same manner I have seen, on the vertical walls of large steam boilers, the heads of nails or rivets covered by a series of enveloping crusts of calcareous matter, usually sulphate of lime; so that a concretionary nodule is formed, preserving a nearly globular shape, when increased to a mass several inches in diameter. In these, as in many travertins, there is often a combination of the concentric and radiated structure, and the last-mentioned character is one of those in which the English magnesian limestone agrees with the Italian travertins.

Another point of resemblance between these rocks, in other respects so dissimilar, is the interference of one sphere with another, and the occasional occurrence of cavities and vacuities, constituting what has been called a honeycombed structure, and also the frequent interposition of loose incoherent matter, between different solid spheroidal concretions. Yet, notwithstanding such points of analogy, Professor Sedgwick observes, that there are proofs of the concretionary arrangement in the magnesian limestone having taken place subsequently to original deposition, for in this case the spheroidal forms are often quite independent of the direction of the laminæ.*

* Geol. Trans. 2nd series, vol. iii. p. 37. I have lately seen some specimens of spheroidal magnesian limestone, collected by

Bulicami of Viterbo.—I must not attempt to describe all the places in Italy where the constant formation of limestone may be seen, as on the Silaro, near Pæstum, on the Velino at Terni, and near the Bulicami, or hot baths in the vicinity of Viterbo. About a mile and a half north of the latter town, in the midst of a sterile plain of volcanic sand and ashes, a monticule is seen, about twenty feet high and five hundred yards in circumference, entirely composed of concretionary travertin. The laminæ are very thin, and their minute undulations so arranged, that the whole mass has at once a concentric and radiated structure. This rock has been largely quarried for lime, and much of it appears to have been removed. It has evidently been formed gradually, like the conical mounds of the geysers in Iceland, by a small jet or fountain of calcareous water, which overflowed from the summit of the monticule. A spring of hot water still issues in the neighbourhood, which is conveyed to an open tank used as a bath, the bottom and sides of which, as well as the open conduit which conveys the water, are encrusted with travertin.

Professor Sedgwick, where the calcareous laminæ are intersected at a high angle by the boundary line of the globule of which they form a part. In a former edition I stated, that on visiting Sunderland immediately after examining the travertins of Auvergne and Sicily (the former of lacustrine, the latter of submarine origin), I recognized a striking degree of identity in the prevailing concretionary forms assumed by our magnesian limestone and those of the travertins with the appearance of which my eye was then familiar. I am still convinced that much light would be thrown on the mode of formation of both these rocks by a comparison of the points in which they mutually agree with or differ from each other.

Campagna di Roma.—The country around Rome, like many parts of the Tuscan States already referred to, has been at some former period the site of numerous volcanic eruptions; and the springs are still copiously impregnated with lime, carbonic acid, and sulphuretted hydrogen. A hot spring has lately been discovered near Civita Vecchia, by Signor Riccioli, which deposits alternate beds of a yellowish travertin, and a white granular rock, not distinguishable, in hand specimens, either in grain, colour, or composition, from statuary marble. There is a passage between this and ordinary travertin. The mass accumulated near the spring is in some places about six feet thick.

Lake of the Solfatara.—In the Campagna, between Rome and Tivoli, is the lake of the Solfatara, called also Lago di Zolfo (lacus albula), into which flows continually a stream of tepid water, from a smaller lake situated a few yards above it. The water is a saturated solution of carbonic acid gas, which escapes from it in such quantities in some parts of its surface, that it has the appearance of being actually in ebullition. "I have found by experiment," says Sir Humphry Davy, "that the water taken from the most tranquil part of the lake, even after being agitated and exposed to the air, contained in solution more than its own volume of carbonic acid gas, with a very small quantity of sulphuretted hydrogen. Its high temperature, which is pretty constant at 80° of Fahr., and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford nourishment to vegetable life. The banks of travertin are every where covered with reeds, lichen, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life is going on, the crystallizations of the calcareous matter, which

is every where deposited, in consequence of the escape of carbonic acid, likewise proceed.—There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life."*

The same observer informs us, that he fixed a stick in a mass of travertin covered by the water in the month of May, and in April following he had some difficulty in breaking, with a sharp-pointed hammer, the mass which adhered to the stick, and which was several inches in thickness. The upper part was a mixture of light tufa and the leaves of confervæ: below this was a darker and more solid travertin, containing black and decomposed masses of confervæ; in the inferior part the travertin was more solid, and of a grey colour, but with cavities probably produced by the decomposition of vegetable matter.†

The stream which flows out of this lake fills a canal about nine feet broad and four deep, and is conspicuous in the landscape by a line of vapour which rises from it. It deposits calcareous tufa in this channel, and the Tiber probably receives from it, as well as from numerous other streams, much carbonate of lime in solution, which may contribute to the rapid growth of its delta. A large proportion of the most splendid edifices of ancient and modern Rome are built of travertin, derived from the quarries of Ponte Leucano, where there has evidently been a lake at a remote period, on the same plain as that already described. But the consideration of these would carry us beyond the

* Consolations in Travel, pp. 123—125.

† Id. p. 127.

times of history, and I shall conclude with one more example of the calcareous deposits of this neighbourhood,—those on the Anio.

Travertin of Tivoli.—The waters of the Anio incrust the reeds which grow on its banks, and the foam of the cataract of Tivoli forms beautiful pendant stalactites; but, on the sides of the deep chasm into which the cascade throws itself, there is seen an extraordinary accumulation of horizontal beds of tufa and travertin, from four to five hundred feet in thickness. The section immediately under the temples of Vesta and the Sibyl, displays, in a precipice about four hundred feet high, some spheroids which are from *six to eight feet in diameter*, each concentric layer being about the eighth of an inch in thickness. The annexed diagram exhibits about fourteen feet of this immense mass, as seen in the path cut out of the rock in descending from the temple of Vesta to the Grotto di Nettuno. I have not attempted to express in this drawing the innumerable thin layers of which these magnificent spheroids are composed, but the lines given mark some of the natural divisions into which they are separated by minute variations in the size or colour of the laminæ. The undulations also are much smaller, in proportion to the whole circumference, than in the drawing. The beds *a a* are of hard travertin and soft tufa; below them is a pisolite (*b*), the globules being of different sizes: underneath this appears a mass of concretionary travertin (*c c*), some of the spheroids being of the above-mentioned extraordinary size. In some places (as at *d*) there is a mass of amorphous limestone, or tufa, surrounded by concentric layers. At the bottom is another bed of pisolite (*b*), in which the small nodules are about the size and shape of

beans, and some of them of filberts, intermixed with some smaller oolitic grains. In the tufaceous strata, wood is seen converted into a light tufa.

The following seems the most probable explanation

Fig. 9.

Section of Spheroidal Concretionary Travertin under the Cascade of Tivoli.

of the origin of the rock in this singular position. The Anio flows through a deep irregular fissure or

gorge in the Apennine limestone, which may have been caused by earthquakes. In this deep narrow channel there existed many small lakes, three of which have been destroyed since the time of history, by the erosive action of the torrent, the last of them having remained down to the sixth century of our era.

We may suppose a similar lake of great depth to have existed at some remote period at Tivoli, and that, into this, the waters, charged with carbonate of lime, fell from a height inferior to that of the present cascade. Having, in their passage through the upper lakes, parted with their sand, pebbles, and coarse sediment, they only introduced into this lower pool drift-wood, leaves, and other buoyant substances. In seasons when the water was low, a deposit of ordinary tufa, or of travertin, formed along the bottom; but at other times, when the torrent was swollen, the pool must have been greatly agitated, and every small particle of carbonate of lime which was precipitated must have been whirled round again and again in various eddies, until it acquired many concentric coats, so as to resemble oolitic grains. If the violence of the motion be sufficient to cause the globule to be suspended for a sufficient length of time, it would grow to the size of a pea, or much larger. Small fragments of vegetable stems being incrusted on the sides of the stream, and then washed in, would form the nucleus of oval globules, and others of irregular shapes would be produced by the resting of fragments for a time on the bottom of the basin, where, after acquiring an unequal thickness of travertin on one side, they would again be set in motion. Sometimes globules, projecting above the general level of a stratum, would attract, by chemical affinity, other matter in the act of precipi-

tation, and thus growing on all sides, with the exception of the point of contact, might at length form spheroids nearly perfect and many feet in diameter. Masses might increase above and below, so that a vertical section might afterwards present the phenomenon so common at Tivoli, where the nucleus of some of the concentric circles has the appearance of having been suspended, without support, in the water, until it became a spheroidal mass of great dimensions.

It is probable that the date of the greater portion of this calcareous formation may be anterior to the era of history, for we know that there was a great cascade at Tivoli in very ancient times; but, in the upper part of the travertin, is shown the hollow left by a wheel, in which the outer circle and the spokes have been decomposed, and the spaces which they filled have been left void. It seems impossible to explain the position of this mould, without supposing that the wheel was imbedded before the lake was drained.

Calcareous springs in the Caucasus. — Pallas, in his journey along the Caucasus, a country now subject, from time to time, to be rent and fissured by violent earthquakes, enumerates a great many hot springs, which have deposited monticules of travertin precisely analogous in composition and structure to those of the baths of San Filippo and other localities in Italy. When speaking of the tophus-stone, as he terms these limestones, he often observes that it is *snow-white*, a description which is very applicable to the newer part of the deposit at San Filippo, where it has not become darkened by weathering. In many localities in the

regions between the Caspian and Black Seas, where subterranean convulsions are frequent, travellers mention calc-sinter as an abundant product of hot springs. Near the shores of the Lake Urmia (or Maragha), for example, a marble which is much used in ornamental architecture is rapidly deposited by a thermal spring.*

It is probable that the zoophytic and shelly limestones, which constitute the coral reefs of the Indian and Pacific Oceans, are supplied with carbonate of lime and other mineral ingredients from submarine springs, and that their heat, as well as their earthy and gaseous contents, may promote the development of corals, sponges, and testacea, just as vegetation is quickened by similar causes in the lake of the Solfatara before described. But of these reefs and their probable origin I shall again have occasion to speak in the third book.

Sulphureous and gypseous springs.—The quantity of other mineral ingredients wherewith springs in general are impregnated, is insignificant in comparison to lime, and this earth is most frequently combined with carbonic acid. But, as sulphuric acid and sulphuretted hydrogen are very frequently supplied by springs, gypsum may, perhaps, be deposited largely in certain seas and lakes. The gypseous precipitates, however, hitherto known on the land, appear to be confined to a very few springs. Those at Baden, near Vienna, which feed the public bath, may be cited as examples. Some of these supply, singly, from 600 to 1000 cubic feet of water per hour, and deposit a fine powder, composed

* Hoff, Geschichte, &c. vol. ii. p. 114.

of a mixture of sulphate of lime, with sulphur and muriate of lime.*

Siliceous springs. — *Azores.* — In order that water should hold a very large quantity of silica in solution, it seems necessary that it should be raised to a high temperature †; and as it may retain a greater heat under the pressure of the sea than in the atmosphere, submarine springs may, perhaps, be more charged with silex than any to which we have access. The hot springs of the Valle das Furnas, in the Island of St. Michael, rising through volcanic rocks, precipitate vast quantities of siliceous sinter, as it is usually termed. Around the circular basin of the largest spring, called "the Caldeira," which is between twenty and thirty feet in diameter, alternate layers are seen of a coarser variety of sinter mixed with clay, including grass, ferns, and reeds, in different states of petrifaction. Wherever the water has flowed, sinter is found rising in some places eight or ten inches above the ordinary level of the stream. The herbage and leaves, more or less incrusted with silex, are said to exhibit all the successive steps of petrifaction, from the soft state to a complete conversion into stone; but in some instances, alumina, which is likewise deposited from the hot waters, is the mineralizing material. Branches of the same ferns which now flourish in the island are found completely petrified, preserving the same appearance as when vegetating, except that they acquire an ash-gray colour. Fragments of wood, and one entire bed from three to five feet in depth, com-

* C. Prevost, Essai sur la Constitution Physique du Bassin de Vienne, p. 10.

† Daubeny on Volcanos, p. 222.

posed of reeds now common in the island, have become completely mineralized.

The most abundant variety of siliceous sinter occurs in layers from a quarter to half an inch in thickness, accumulated on each other often to the height of a foot and upwards, and constituting parallel, and for the most part horizontal, strata many yards in extent. This sinter has often a beautiful semi-opalescent lustre. One of the varieties differs from that of Iceland and Ischia in the larger proportion of water it contains, and in the absence of alumina and lime. A recent breccia is also in the act of forming, composed of obsidian, pumice, and scoriæ, cemented by siliceous sinter.*

Geysers of Iceland. — But the hot springs in various parts of Iceland, particularly the celebrated geysers, afford the most remarkable example of the deposition of silex.† The circular reservoirs into which the geysers fall, are filled in the middle with a variety of opal, and round the edges with sinter. The plants incrusted with the latter substance have much the same appearance as those incrusted with calcareous tufa in our own country.

In some of the thermal waters of Iceland a vesicular rock is formed, containing portions of vegetables more or less completely silicified; and amongst other products of springs in this island, is that admixture of clay and silica, called tripoli.

By analysis of the water, Mr. Faraday has ascertained that the solution of the silex is promoted by the presence of the alkali, soda. He suggests that the deposition of silica in an insoluble state takes

* Dr. Webster on the Hot Springs of Furnas, Ed. Phil. Journ., vol. vi. p. 306.

† See a cut of the Icelandic geyser, Book II. chap. 19.

place partly because the water when cooled by exposure to the air is unable to retain as much silica as when it issues from the earth at a temperature of 180° or 190° Fahr.; and partly because the evaporation of the water decomposes the compound of silica and soda which previously existed. This last change is probably hastened by the carbonic acid of the atmosphere uniting with the soda. The alkali, when disunited from the silica, would readily be dissolved in and removed by running water.*

Ischia. — It has been found, by recent analysis, that several of the thermal waters of Ischia are impregnated with a certain proportion of silica. Some of the hot vapours of that island are above the temperature of boiling water: and many fissures, near Monte Vico, through which the hot steam passes, are coated with a siliceous incrustation, first noticed by Dr. Thompson under the name of fiorite.

Ava, &c.—It has been often stated that the Danube has converted the external part of the piles of Trajan's bridge into silex; the Irawadi, in Ava, has been supposed, ever since the time of the Jesuit Padre Duchatz, to have the same petrifying power, as also Lough Neagh, in Ireland. Modern researches, however, in the Burman empire, have thrown doubt upon the lapidifying property of the Ava river†; there is certainly no foundation for the story in regard to Lough Neagh, and probably none in regard to the Danube.

Mineral waters, even when charged with a small proportion of silica, as those of Ischia, may supply certain species of corals and sponges with matter for

* Barrow's Iceland, p. 209.

† Dr. Buckland, Geol. Trans., second series, vol. ii. part iii. p. 384.

their siliceous secretions; but when in a volcanic archipelago, or a region of submarine volcanos, there are springs so saturated with silica as those of Iceland or the Azores, we may expect layers and nodules of silex and chert to be spread out far and wide over the bed of the sea, and interstratified with shelly and calcareous deposits, which may be forming there, or with matter derived from wasting cliffs or volcanic ejections.

Ferruginous springs. — The waters of almost all springs contain some iron in solution; and it is a fact familiar to all, that many of them are so copiously impregnated with this metal, as to stain the rocks or herbage through which they pass, and to bind together sand and gravel into solid masses. We may naturally, then, conclude that this iron, which is constantly conveyed from the interior of the earth into lakes and seas, and which does not escape again from them into the atmosphere by evaporation, must act as a colouring and cementing principle in the subaqueous deposits now in progress. It will be afterwards seen that many sandstones and other rocks in the sedimentary strata of ancient lakes and seas are bound together or coloured by iron, and this fact presents us with a striking point of analogy between the state of things at very different epochs. In those older formations we meet with great abundance of carbonate and sulphate of iron; and in chalybeate waters at present, this metal is most frequently in the state of a carbonate, as in those of Tunbridge, for example. Sulphuric acid, however, is often the solvent, which is in many cases derived from the decomposition of pyrites.

Brine springs. — *Cheshire.* — So great is the quantity of muriate of soda in some springs, that they yield

one fourth of their weight in salt. They are rarely, however, so saturated, and generally contain, intermixed with salt, carbonate and sulphate of lime, magnesia, and other mineral ingredients. The brine springs of Cheshire are the richest in our country; those of Barton and Northwich being almost fully saturated. These brine springs rise up through strata of sandstone and red marl, which contain large beds of rock salt. The origin of the brine, therefore, may be derived in this and many other instances from beds of fossil salt; but as muriate of soda is one of the products of volcanic emanations and of springs in volcanic regions, the original source of salt may be as deep seated as that of lava.

Dead Sea. — The waters of the Dead Sea contain scarcely any thing except muriatic salts, which lends countenance, observes Dr. Daubeny, to the volcanic origin of the surrounding country, these salts being frequent products of volcanic eruptions. Many springs in Sicily contain muriate of soda, and the "fiume salso," in particular, is impregnated with so large a quantity, that cattle refuse to drink of it.

Auvergne.—A hot spring, rising through granite, at Saint Nectaire, in Auvergne, may be mentioned as one of many, containing a large proportion of muriate of soda, together with magnesia and other ingredients.*

Carbonated springs. — *Auvergne.* — Carbonic acid gas is very plentifully disengaged from springs in almost all countries, but particularly near active or extinct volcanos. This elastic fluid has the property of decomposing many of the hardest rocks with which it comes in contact, particularly that numerous class

* Annales de l'Auvergne, tome i. p. 234.

in whose composition felspar is an ingredient. It renders the oxide of iron soluble in water, and contributes, as was before stated, to the solution of calcareous matter. In volcanic districts these gaseous emanations are not confined to springs, but rise up in the state of pure gas from the soil in various places. The Grotto del Cane, near Naples, affords an example, and prodigious quantities are now anuually disengaged from every part of the Limagne d'Auvergne, where it appears to have been developed in equal quantity from time immemorial. As the acid is invisible, it is not observed, except an excavation be made, wherein it immediately accumulates, so that it will extinguish a candle. There are some springs in this district, where the water is seen bubbling and boiling up with much noise, in consequence of the abundant disengagement of this gas. The whole vegetation is affected, and many trees, such as the walnut, flourish more luxuriantly than they would otherwise do in the same soil and climate — the leaves probably absorbing carbonic acid. This gas is found in springs rising through the granite near Clermont, as well as in the tertiary limestones of the Limagne.* In the environs of Pont-Gibaud, not far from Clermont, a rock belonging to the gneiss formation, in which lead-mines are worked, has been found to be quite saturated with carbonic acid gas, which is constantly disengaged. The carbonates of iron, lime, and manganese are so dissolved, that the rock is rendered soft, and the quartz alone remains unattacked.† Not far off is the small volcanic cone of Chaluzet, which once broke up through the gneiss, and sent forth a lava-stream.

* Le Coq, Annales de l'Auvergne, tome i. p. 217. May, 1828.

† Ann. Scient. de l'Auvergne, tome ii. June, 1829.

Disintegration of granite.—The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighbourhood of Clermont. This decay was called by Dolomieu, "la maladie du granite;" and the rock may with propriety be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures.

In the plains of the Po, between Verona and Parma, especially at Villa Franca, south of Mantua, I observed great beds of alluvium, consisting chiefly of primary pebbles, percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are for the most part incrusted with calc-sinter: and the rounded blocks of gneiss, which have all the outward appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces.

The subtraction of many of the elements of rocks by the solvent power of carbonic acid, ascending both in a gaseous state and mixed with spring-water in the crevices of rocks, must be one of the most powerful sources of those internal changes and re-arrangements of particles so often observed in strata of every age. The calcareous matter, for example, of shells is often entirely removed and replaced by carbonate of iron, pyrites, silex, or some other ingredient, such as mineral waters usually contain in solution. It rarely happens, except in limestone rocks, that the carbonic acid can dissolve all the constituent parts of the mass; and for this reason, probably, calcareous rocks are almost the only ones in which great caverns and long winding passages are found.

Petroleum springs.—Springs impregnated with pe-

troleum, and the various minerals allied to it, as bitumen, naphtha, asphaltum, and pitch, are very numerous, and are, in many cases, undoubtedly connected with subterranean fires, which raise or sublime the more subtle parts of the bituminous matters contained in rocks. Many springs in the territory of Modena and Parma, in Italy, produce petroleum in abundance; but the most powerful, perhaps, yet known, are those on the Irawadi, in the Burman empire. In one locality there are said to be 520 wells, which yield annually 400,000 hogsheads of petroleum.*

Fluid bitumen is seen to ooze from the bottom of the sea, on both sides of the island of Trinidad, and to rise up to the surface of the water. Near Cape La Braye there is a vortex which, in stormy weather, according to Captain Mallet, gushes out, raising the water five or six feet, and covers the surface for a considerable space with petroleum, or tar; and the same author quotes Gumilla, as stating in his "Description of the Orinoco," that, about seventy years ago, a spot of land on the western coast of Trinidad, near halfway between the capital and an Indian village, sank suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants.†

Pitch lake of Trinidad.—It is probable that the great pitch lake of Trinidad owes its origin to a similar cause; and Dr. Nugent has justly remarked, that in that district all the circumstances are now combined from which deposits of pitch may have originated. The Orinoco has for ages been rolling down great quantities of woody and vegetable bodies

* Symes, Embassy to Ava, vol. ii. — Geol. Trans., second series, vol. ii. part iii. p. 388.

† Dr. Nugent, Geol. Trans. vol. i. p. 69.

into the surrounding sea, where, by the influence of currents and eddies, they may be arrested and accumulated in particular places. The frequent occurrence of earthquakes and other indications of volcanic action in those parts lends countenance to the opinion, that these vegetable substances may have undergone, by the agency of subterranean fire, those transformations and chemical changes which produce petroleum, and this may, by the same causes, be forced up to the surface, where, by exposure to the air, it becomes inspissated, and forms the different varieties of pure and earthy pitch, or asphaltum, so abundant in the island.*

The bituminous shales, so common in geological formations of different ages, as also many stratified deposits of bitumen and pitch, seem clearly to attest that, at former periods, springs, in various parts of the world, were as commonly impregnated as now with bituminous matter, carried down, probably, by rivers into lakes and seas. It will, indeed, be easy to show, that a large portion of the finer particles and the more crystalline substances found in sedimentary rocks of different ages are composed of the same elements as are now held in solution by springs, while the coarser materials bear an equally strong resemblance to the alluvial matter in the beds of existing torrents and rivers.

* Dr. Nugent, Geol. Trans. vol. i. p. 67.

CHAPTER IV.

REPRODUCTIVE EFFECTS OF RUNNING WATER.

Reproductive effects of running water — Division of Deltas into lacustrine, mediterranean, and oceanic — Lake deltas — Growth of the delta of the Upper Rhone in the Lake of Geneva — Chronological computations of the age of deltas — Recent deposits in Lake Superior (p. 338.) — Deltas of inland seas — Rapid shallowing of the Baltic — Marine delta of the Rhone (p. 341.) — Various proofs of its increase — Stony nature of its deposits — Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic — Rapid conversion of that gulf into land — Mineral characters of the new deposits — Delta of the Nile (p. 349.) — Its increase since the time of Homer — Its growth why checked at present.

Having considered the destroying and transporting agency of running water, we have now to examine the reproductive effects of the same cause. The aggregate amount of deposits accumulated in a given time at the mouths of rivers, where they enter a lake or sea, affords clearer data for estimating the energy of the excavating power of running water on the land, than the separate study of the operations of the same cause in the countless ramifications into which every great system of valleys is divided. I shall therefore proceed to select some of the leading facts at present ascertained respecting the growth of deltas, and shall then offer some general observations on the quantity of sediment transported by rivers, and the manner of its distribution beneath the waters of lakes and seas.

Division of deltas into lacustrine, mediterranean, and oceanic.—Deltas may be divided into, first, those which are formed in lakes; secondly, those in inland seas; and thirdly, those on the borders of the ocean. The most characteristic distinction between the lacustrine and marine deltas consists in the nature of the organic remains which become imbedded in their deposits; for, in the case of a lake, it is obvious that these must consist exclusively of such genera of animals as inhabit the land or the waters of a river or lake; whereas, in the other case, there will be an admixture and most frequently a predominance of animals which inhabit salt water. In regard, however, to the distribution of inorganic matter, the deposits of lakes and inland seas are formed under very analogous circumstances, and may be distinguished from those on the shores of the great ocean, where the tides cooperating with currents give rise to another class of phenomena. In lakes and inland seas, even of the largest dimensions, the tides are almost insensible, but the currents, as will afterwards appear, sometimes run with considerable velocity.

DELTAS IN LAKES.

Lake of Geneva.—It is natural to begin our examination with an inquiry into the new deposits in lakes, as they exemplify the first reproductive operations in which rivers are engaged when they convey the detritus of rocks and the ingredients of mineral springs from mountainous regions. The accession of new land at the mouth of the Rhone, at the upper end of the Lake of Geneva, or the Leman Lake, presents us with an example of a considerable thickness of strata which

have accumulated since the historical era. This sheet of water is about thirty-seven miles long, and its breadth is from two to eight miles. The shape of the bottom is very irregular, the depth having been found, by late measurements, to vary from 20 to 160 fathoms.* The Rhone, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vallais, (Portus Valesiæ of the Romans,) once situated at the water's edge, at the upper end, is now more than a mile and a half inland —this intervening alluvial tract having been acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river, and full of marshes.

Mr. De la Beche found, after numerous soundings in all parts of the lake, that there was a pretty uniform depth of from 120 to 160 fathoms throughout the central region, and, on approaching the delta, the shallowing of the bottom began to be very sensible at a distance of about a mile and three quarters from the mouth of the Rhone; for a line drawn from St. Gingoulph to Vevey, gives a mean depth of somewhat less than six hundred feet, and from that part to the Rhone, the fluviatile mud is always found along the bottom.† We may state, therefore, that the strata annually produced are about two miles in length: so that, notwithstanding the great depth of the lake, the new deposits are not inclined at a high angle; the dip of the beds, indeed, is so slight, that they would be termed, in ordinary geological language, horizontal.

* De la Beche, Ed. Phil. Journ. vol. ii. p. 107. Jan. 1820.

† De la Beche, MS.

The strata probably consist of alternations of finer and coarser particles; for, during the hotter months from April to August, when the snows melt, the volume and velocity of the river are greatest, and large quantities of sand, mud, vegetable matter, and drift-wood are introduced; but, during the rest of the year, the influx is comparatively feeble, so much so, that the whole lake, according to Saussure, stands six feet lower. If, then, we could obtain a section of the accumulation formed in the last eight centuries, we should see a great series of strata, probably from 600 to 900 feet thick, and nearly two miles in length, inclined at a very slight angle. In the mean time, a great number of smaller deltas are growing around the borders of the lake, at the mouths of rapid torrents, which pour in large masses of sand and pebbles. The body of water in these torrents is too small to enable them to spread out the transported matter over so extensive an area as the Rhone does. Thus, for example, there is a depth of eighty fathoms within half a mile of the shore, immediately opposite the great torrent which enters east of Ripaille, so that the dip of the strata in that minor delta must be about four times as great as those deposited by the main river at the upper extremity of the lake.*

Chronological computations of the age of deltas.—The capacity of this basin being now ascertained, it would be an interesting subject of inquiry, to determine in what number of years the Leman Lake will be converted into dry land. It would not be very difficult to obtain the elements for such a calculation, so as to approximate at least to the quantity of time required

* De la Beche, MS.

for the accomplishment of the result. The number of cubic feet of water annually discharged by the river into the lake being estimated, experiments might be made in the winter and summer months, to determine the proportion of matter held in suspension or in chemical solution by the Rhone. It would be also necessary to allow for the heavier matter drifted along at the bottom, which might be estimated on hydrostatical principles, when the average size of the gravel and the volume and velocity of the stream at different seasons were known. Supposing all these observations to have been made, it would be more easy to calculate the future than the former progress of the delta, because it would be a laborious task to ascertain, with any degree of precision, the original depth and extent of that part of the lake which is already filled up. Even if this information were actually obtained by borings, it would only enable us to approximate within a certain number of centuries to the time when the Rhone began to form its present delta; but this would not give us the date of the origin of the Leman Lake in its present form, because the river may have flowed into it for thousands of years, without importing any sediment whatever. Such would have been the case, if the waters had first passed through a chain of upper lakes; and that this was actually the fact, is indicated by the course of the Rhone between Martigny and the Lake of Geneva, and, still more decidedly, by the channels of many of its principal feeders.

If we ascend, for example, the valley through which the Dranse flows, we find that it consists of a succession of basins, one above the other, in each of which there is a wide expanse of flat alluvial lands, separated from the next basin by a rocky gorge, once evidently the

barrier of a lake. The river has filled these lakes, one after the other, and has partially cut through the barriers, which it is still gradually eroding to a greater depth. The examination of almost all valleys in mountainous districts affords similar proofs of the obliteration of a series of lakes, by the filling up of hollows and the cutting through of rocky barriers — a process by which running water ever labours to produce a more uniform declivity. Before, therefore, we can pretend even to hazard a conjecture as to the era at which any particular delta commenced, we must be thoroughly acquainted with the geographical features and geological history of the whole system of higher valleys which communicate with the main stream, and all the changes which they have undergone since the last series of convulsions which agitated and altered the face of the country.

The probability, therefore, of error in our chronological computations where we omit to pay due attention to these circumstances, increases in proportion to the time that may have elapsed since the last disturbance of the country by subterranean movements, and in proportion to the extent of the hydrographical basin on which we may happen to speculate. The Alpine rivers of Vallais are prevented at present from contributing their sedimentary contingent to the lower delta of the Rhone in the Mediterranean, because they are intercepted by the Leman Lake; but when this is filled, they will transport as much, or nearly as much, matter to the sea, as they now pour into that lake. They will then flow through a long, flat, alluvial plain, between Villeneuve and Geneva, from two to eight miles in breadth, which will present no superficial marks of the existence of a thickness of more than one thousand

feet of recent sediment below. Many hundred alluvial tracts of equal, and some of much greater area, may be seen if we follow up the Rhone from its termination in the Mediterranean, or explore the valleys of many of its principal tributaries.

What, then, shall we think of the presumption of De Luc, Kirwan, and their followers, who confidently deduced from the phenomena of modern deltas the recent origin of the present form of our continents, without pretending to have collected any one of the numerous data by which so complicated a problem can be solved? Had they, after making all the necessary investigations, succeeded in proving, as they desired, that the lower delta of the Rhone, and the new deposits at the mouths of several other rivers, whether in lakes or seas, had required about four thousand years to attain their present dimensions, the conclusion would have been fatal to the chronological theories which they were anxious to confirm.

Lake Superior.—Lake Superior is the largest body of fresh water in the world, being about 1500 geographical miles in circumference when we follow the sinuosities of its coasts, and its length, on a curved line drawn through its centre, being about 360, and its extreme breadth 140 geographical miles. Its average depth varies from 80 to 150 fathoms; but, according to Captain Bayfield, there is reason to think that its greatest depth would not be overrated at two hundred fathoms *, so that its bottom is, in some parts, nearly six hundred feet below the level of the Atlantic, its surface about as much above it. There are appearances in different parts of this, as of the other Canadian

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

lakes, leading us to infer that its waters formerly occupied a much higher level than they reach at present; for at a considerable distance from the present shores, parallel lines of rolled stones and shells are seen rising one above the other, like the seats of an amphitheatre. These ancient lines of shingle are exactly similar to the present beaches in most bays, and they often attain an elevation of forty or fifty feet above the present level.

As the heaviest gales of wind do not raise the waters more than three or four feet*, the elevated beaches must either be referred to the subsidence of the lake at former periods, in consequence of the wearing down of its barrier, or to the upraising of the shores by earthquakes, like those which have produced similar phenomena on the coast of Chili. The streams which discharge their waters into Lake Superior are several hundred in number, without reckoning those of smaller size; and the quantity of water supplied by them is many times greater than that discharged at the Falls of St. Mary, the only outlet. The evaporation, therefore, is very great, and such as might be expected from so vast an extent of surface.

On the northern side, which is encircled by primary mountains, the rivers sweep in many large boulders with smaller gravel and sand, chiefly composed of granitic and trap rocks. There are also currents in the lake, in various directions, caused by the continued

* Captain Bayfield remarks, that Dr. Bigsby, to whom we are indebted for several communications respecting the geology of the Canadian lakes, was misinformed by the fur traders in regard to the extraordinary height (twenty or thirty feet) to which he asserts that the autumnal gales will raise the water of Lake Superior. — Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 7. 1829.

prevalence of strong winds, and to their influence we may attribute the diffusion of finer mud far and wide over great areas; for, by numerous soundings made during the late survey, it was ascertained that the bottom consists generally of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree, as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third white, hardening into a substance resembling pipe-clay.* From these statements, the geologist will not fail to remark how closely these recent lacustrine formations in America resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France. In both cases, many of the genera of shells most abundant, as Lymnea and Planorbis, are the same; and in regard to other classes of organic remains, there must be the closest analogy, as I shall endeavour more fully to explain when speaking of the imbedding of plants and animals in recent deposits.

DELTAS OF INLAND SEAS.

Baltic. — Having thus briefly considered some of the lacustrine deltas now in progress, we may next turn our attention to those of inland seas.

The shallowing and conversion into land of many parts of the Baltic, especially the Gulfs of Bothnia and Finland, have been demonstrated by a series of accu-

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

rate observations, for which we are in a great measure indebted to the animated controversy which has been kept up, since the middle of the last century, concerning the gradual lowering of the level of the Baltic. I shall revert to this subject when treating of the slow and insensible upheaving of the land in certain parts of Sweden, a movement which produces an apparent fall in the level of the waters, both of the Baltic and the ocean.* It is only necessary to state in this place, that the rapid gain of low tracts of land near Torneo, Pitea and Lulea, near the head of the Gulf of Bothnia, are due to the joint operation of two causes — the influx of sediment from numerous rivers, and a slow and general upward movement of the land itself, and bed of the sea, at the rate of several feet in a century.

Delta of the Rhone. — We may now turn our attention to some of the principal deltas of the Mediterranean, for no other inland sea affords so many examples of accessions of new lands at the mouths of rivers within the records of authentic history. The lacustrine delta of the Rhone in Switzerland has already been considered, and its contemporaneous marine delta may now be described. Scarcely has the river passed out of the Lake of Geneva, before its pure waters are again filled with sand and sediment by the impetuous Arve, descending from the highest Alps, and bearing along in its current the granitic detritus annually brought down by the glaciers of Mont Blanc. The Rhone afterwards receives vast contributions of transported

* Since writing the former edition, I have visited Sweden, and removed the doubts which I before entertained and expressed respecting the alleged gradual elevation of the land in Scandinavia. — See Book ii. chap. xvii.

matter from the Alps of Dauphiny, and the primary and volcanic mountains of Central France; and when at length it enters the Mediterranean, it discolours the blue waters of that sea with a whitish sediment, for the distance of between six and seven miles, throughout which space the current of fresh water is perceptible.

Proofs of its increase since historical periods.— Strabo's description of the delta is so inapplicable to its present configuration, as to attest a complete alteration in the physical features of the country since the Augustan age. It appears, however, that the head of the delta, or the point at which it begins to ramify, has remained unaltered since the time of Pliny, for he states that the Rhone divided itself at Arles into two arms. This is the case at present; one of the branches being now called Le Petit Rhône, which is again subdivided before entering the Mediterranean. The advance of the base of the delta, in the last eighteen centuries, is demonstrated by many curious antiquarian monuments. The most striking of these is the great detour made by the old Roman road from Ugernum to Beziers (part of the high road between Aix, *Aquæ Sextiæ*, and Nismes, *Nemausus*). It is clear that, when this was first constructed, it was impossible to pass in a direct line as now, across the delta, and that either the sea or marshes intervened in a tract now consisting of terra firma.* Astruc also remarks, that all the places on low lands, lying to the north of the old Roman road between Nismes and Beziers, have names of Celtic origin, evidently given to them by the first inhabitants of the country; whereas, the

* Mém. d'Astruc, cited by Von Hoff, vol. i. p. 228.

places lying south of that road, towards the sea, have names of Latin derivation, and were clearly founded after the Roman language had been introduced.

Another proof, also, of the great extent of land which has come into existence since the Romans conquered and colonized Gaul, is derived from the fact, that the Roman writers never mention the thermal waters of Balaruc in the delta, although they were well acquainted with those of Aix, and others still more distant, and attached great importance to them, as they invariably did to all hot springs. The waters of Balaruc, therefore, must have formerly issued under the sea—a common phenomenon on the borders of the Mediterranean; and on the advance of the delta they continued to flow out through the new deposits.

Among the more direct proofs of the increase of land, we find that Mese, described under the appellation of Mesua Collis by Pomponius Mela*, and stated by him to be nearly an island, is now far inland. Notre Dame des Ports, also, was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, and is now two leagues from the sea. Several old lines of towers and sea-marks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners; which may well be conceived, when we state that the tower of Tignaux, erected on the shore so late as the year 1737, is already a French mile remote from it.†

By the confluence of the Rhone and the currents of

* Lib. II. c. v.

† Bouche, Chorographie et Hist. de Provence, vol. i. p. 23., cited by Hoff, vol. i. p. 290.

the Mediterranean, driven by winds from the south, sand-bars are often formed across the mouths of the river : by these means considerable spaces become divided off from the sea, and subsequently from the river also, when it shifts its channels of efflux. As some of these lagoons are subject to the occasional ingress of the river when flooded, and of the sea during storms, they are alternately salt and fresh. Others, after being filled with salt water, are often lowered by evaporation till they become more salt than the sea; and it has happened, occasionally, that a considerable precipitate of muriate of soda has taken place in these natural salterns. During the latter part of Napoleon's career, when the excise laws were enforced with extreme rigour, the police was employed to prevent such salt from being used. The fluviatile and marine shells enclosed in these small lakes often live together in brackish water; but the uncongenial nature of the fluid usually produces a dwarfish size, and sometimes gives rise to strange varieties in form and colour.

Captain Smyth, in the late survey of the coast of the Mediterranean, found the sea, opposite the mouth of the Rhone, to deepen gradually from four to forty fathoms, within a distance of six or seven miles, over which the discoloured fresh water extends; so that the inclination of the new deposits must be too slight to be appreciable in such an extent of section as a geologist usually obtains in examining ancient formations. When the wind blew from the south-west, the ships employed in the survey were obliged to quit their moorings; and when they returned, the new sand-banks in the delta were found covered over with a great abundance of marine shells. By this means,

we learn how occasional beds of drifted marine shells may become interstratified with fresh-water strata at a river's mouth.

Stony nature of its deposits.—That a great proportion, at least, of the new deposit in the delta of the Rhone, consists of *rock*, and not of loose incoherent matter, is perfectly ascertained. In the Museum at Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter, including multitudes of broken shells of recent species. The observations lately made on this subject corroborate the former statement of Marsilli, that the earthy deposits of the coast of Languedoc form a stony substance, for which reason he ascribed a certain bituminous, saline, and glutinous nature to the substances brought down with sand by the Rhone.* If the number of mineral springs charged with carbonate of lime which fall into the Rhone and its feeders in different parts of France be considered, we shall feel no surprise at the lapidification of the newly deposited sediment in this delta. It should be remembered, that the fresh water introduced by rivers, being lighter than the water of the sea, floats over the latter, and remains upon the surface for a considerable distance. Consequently, it is exposed to as much evaporation as the waters of a lake; and the area over which the river-water is spread, at the junction of great rivers and the sea, may well be compared, in point of extent, to that of considerable lakes.

Now, it is well known, that so great is the quantity

* Hist. Phys. de la Mer.

of water carried off by evaporation in some lakes, that it is nearly equal to the water flowing in; and in some inland seas, as the Caspian, it is quite equal. We may, therefore, well suppose, that, in cases where a strong current does not interfere, the greater portion not only of the matter held mechanically in suspension, but of that also which is in chemical solution, may be precipitated at no great distance from the shore. When these finer ingredients are extremely small in quantity, they may only suffice to supply crustaceous animals, corals, and marine plants, with the earthy particles necessary for their secretions; but whenever it is in excess (as generally happens if the basin of a river lie partly in a district of active or extinct volcanos), then will solid deposits be formed, and the shells will at once be included in a rocky mass.

Delta of the Po.—The Adriatic presents a great combination of circumstances favourable to the rapid formation of deltas—a gulf receding far into the land—a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adige, besides numerous minor streams, draining on the one side a great crescent of the Alps, and on the other some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste, where the Isonzo enters, down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than one hundred miles in length, which, within the last two thousand years, have increased from *two to twenty miles in breadth.* The Isonzo, Tagliamento, Piave, Brenta, Adige, and Po, besides many other inferior rivers, contribute to the advance of the coast-line, and to the shallowing of the gulf. The Po and the Adige may now be considered

as entering by one common delta, for two branches of the Adige are connected with arms of the Po.

In consequence of the great concentration of the flooded waters of these streams since the system of embankment became general, the rate of encroachment of the new land upon the Adriatic, especially at that point where the Po and Adige enter, is said to have been greatly accelerated. Adria was a seaport in the time of Augustus, and had, in ancient times, given its name to the gulf; it is now about twenty Italian miles inland. Ravenna was also a seaport, and is now about four Italian miles from the main sea. Yet even before the practice of embankment was introduced, the alluvium of the Po advanced with rapidity on the Adriatic; for Spina, a very ancient city, originally built in the district of Ravenna, at the mouth of a great arm of the Po, was, so early as the commencement of our era, eleven Italian miles distant from the sea.*

The greatest depth of the Adriatic, between Dalmatia and the mouths of the Po, is twenty-two fathoms; but a large part of the Gulf of Trieste and the Adriatic, opposite Venice, is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist partly of mud and partly of rock, the rock being formed of calcareous matter, encrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. i. p. 118.

calcareous precipitates.* Olivi, also, found some deposits of sand, and others of mud, extending half way across the gulf; and he states that their distribution along the bottom was evidently determined by the prevailing current.† It is probable, therefore, that the finer sediment of all the rivers at the head of the Adriatic may be intermingled by the influence of the current; and all the central parts of the gulf may be considered as slowly filling up with horizontal deposits, similar to those of the Subapennine hills, and containing many of the same species of shells. The Po merely introduces at present fine sand and mud; for it carries no pebbles farther than the spot where it joins the Trebia, west of Piacenza. Near the northern borders of the basin, the Isonzo, Tagliamento, and many other streams, are forming immense beds of sand and some conglomerate; for here some high mountains of Alpine limestone approach within a few miles of the sea.

In the time of the Romans, the hot-baths of Monfalcone were on one of several islands of Alpine limestone, between which and the mainland, on the north, was a channel of the sea, about a mile broad. This channel is now converted into a grassy plain, which surrounds the islands on all sides. Among the numerous changes on this coast, we find that the present channel of the Isonzo is several miles to the west of its ancient bed, in part of which, at Ronchi, the old Roman bridge which crossed the Via Appia was lately found buried in fluviatile silt.

Notwithstanding the present shallowness of the

* See Brocchi on the various writers on this subject. Conch. Fos. Subap., vol. i. p. 39.

† Ibid., vol. ii. p. 94.

Adriatic, it is highly probable that its original depth was very great; for if all the low alluvial tracts were taken away from its borders and replaced by sea, the high land would terminate in that abrupt manner which generally indicates, in the Mediterranean, a great depth of water near the shore, except in those spots where sediment imported by rivers and currents has diminished the depth. Many parts of the Mediterranean are now ascertained to be above two thousand feet deep, close to the shore, as between Nice and Genoa; and even sometimes six thousand feet, as near Gibraltar. When, therefore, we find, near Parma, and in other districts in the interior of the Italian peninsula, beds of horizontal tertiary marl attaining a thickness of about two thousand feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above a thousand feet in thickness, and extending seven or eight miles in length, we behold nothing which the analogy of the deltas in the Adriatic might not lead us to anticipate.

Delta of the Nile.—That Egypt was "the gift of the Nile," was the opinion of her priests before the time of Herodotus; but we have no authentic memorials for determining, with accuracy, the dates of successive additions made to the habitable surface of that country. The configuration and composition of the low lands leave no room for doubt, says Rennell, that "the sea once washed the base of the rocks on which the pyramids of Memphis stand, the *present* base of which is washed by the inundation of the Nile, at an elevation of 70 or 80 feet above the Mediterranean. But when we attempt to carry back our ideas to the remote period when the foundation of the delta was first laid, we are lost in the contemplation of so vast an interval

of time."* We know that the base of the delta has been considerably modified since the days of Homer. The ancient geographers mention seven principal mouths of the Nile, of which the most eastern, the Pelusian, has been entirely silted up, and the Mendesian, or Tanitic, has disappeared. The Phatnitic mouth, and the Sebenitic, have been so altered, that the country immediately about them has little resemblance to that described by the ancients. The Bolbitine mouth has increased in its dimensions, so as to cause the city of Rosetta to be at some distance from the sea.

The alterations produced around the Canopic mouth are also important. The city Foah, which, so late as the beginning of the fifteenth century, was on this embouchure, is now more than a mile inland. Canopus, which, in the time of Scylax, was a desolate insular rock, has been connected with the firm land; and Pharos, an island in times of old, now belongs to the continent. Homer says, its distance from Egypt was one day's voyage by sea.† That this should have been the case in Homer's time, Larcher and others have, with reason, affirmed to be in the highest degree improbable; but Strabo has judiciously anticipated their objections, observing, that Homer was probably acquainted with the gradual advance of the land on this coast, and availed himself of this phenomenon to give an air of higher antiquity to the remote period in which he laid the scene of his poem.‡ The Lake Mareotis, also, together with the canal which

* Geog. Syst. of Herod. vol. ii. p. 107.

† Odys., book iv. v. 355.

‡ Lib. I. Part i. pp. 80. 98. Consult Von Hoff, vol. i. p. 244.

connected it with the Canopic arm of the Nile, has been filled with mud, and is become dry. Herodotus observes, "that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams, had formed deltas. Egypt, therefore, he says, like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile, he adds, should by any means have an issue into the Arabian Gulf, it might choke it up with earth in twenty thousand, or even, perhaps, in ten thousand years; and why may not the Nile have filled with mud a still greater gulf in the space of time which has passed before our age?" *

Mud of the Nile.—The analysis of the mud of the Nile gives nearly one half of argillaceous earth, and about one fourth of carbonate of lime, the remainder consisting of water, oxide of iron, and carbonate of magnesia. †

The depth of the Mediterranean is about twelve fathoms at a small distance from the shore of the delta; it afterwards increases gradually to 50, and then suddenly descends to 380 fathoms, which is, perhaps, the original depth of the sea where it has not been rendered shallower by fluviatile matter. The progress of the delta in the last two thousand years affords, perhaps, no measure for estimating its rate of growth when it was an inland bay, and had not yet protruded itself beyond the coast-line of the Mediterranean. A powerful current now sweeps along the shores of Africa, from the Straits of Gibraltar to the prominent

* Euterpe, XI.

† Girard, Mém. sur l'Egypte, tome i. pp. 348. 382.

convexity of Egypt, the western side of which is continually the prey of the waves; so that not only are fresh accessions of land checked, but ancient parts of the delta are carried away. By this cause Canopus and some other towns have been overwhelmed: but to this subject I shall again refer when speaking of tides and currents.

CHAPTER V.

OCEANIC DELTAS.

Oceanic deltas — Deltas of the Ganges and Burrampooter — Its size — Rate of advance, and nature of its deposits — Formation and destruction of islands — Abundance of crocodiles — Inundations — Delta of the Mississippi (p. 360.) — Deposits of drift wood — Gradual filling up of the Yellow Sea — Estimate of the quantity of mud carried down by the Ganges — Formation of valleys illustrated by the growth of deltas — Grouping of new strata in general (p. 367.) — Convergence of deltas — Conglomerates — Various causes of stratification — Direction of laminæ — Remarks on the interchange of land and sea.

The remaining class of deltas are those in which rivers, on entering the sea, are exposed to the influence of the tides. In this case it frequently happens that an estuary is produced, or negative deltá, as Rennell termed it, where, instead of any encroàchment of the land upon the sea, the ocean enters the river's mouth, and penetrates into the land beyond the general coast-line. Where this happens, the tides and currents are the predominating agents in the distribution of transported sediment. The phenomena, therefore, of such estuaries, will be treated of when the movements of the ocean come under consideration. But whenever the volume of fresh water is so great as to counteract and almost neutralize the force of tides and currents, and in all cases where these agents have not sufficient power to remove to a distance the whole of the sedi-

ment periodically brought down by rivers, oceanic deltas are produced. Of these, I shall now select a few illustrative examples.

Delta of the Ganges. — The Ganges and the Burrampooter descend, from the highest mountains in the world, into a gulf which runs 225 miles into the continent. The Burrampooter is somewhat the larger river of the two; but it first takes the name of the Megna when joined by a smaller stream so called, and afterwards loses this second name on its union with the Ganges, at the distance of about forty miles from the sea. The area of the delta of the Ganges (without including that of the Burrampooter, which has now become conterminous) is considerably more than double that of the Nile; and its head commences at a distance of 220 miles, in a direct line from the sea. Its base is two hundred miles in length, including the space occupied by the two great arms of the Ganges which bound it on either side. That part of the delta which borders on the sea is composed of a labyrinth of rivers and creeks, all filled with salt water, except those immediately communicating with the principal arm of the Ganges. This tract alone, known by the name of the Woods, or Sunderbunds, a wilderness infested by tigers and alligators, is, according to Rennell, equal in extent to the whole principality of Wales.*

On the sea-coast there are eight great openings, each of which has evidently, at some ancient period, served in its turn as the principal channel of discharge. Although the flux and reflux of the tide extend even to the head of the delta when the river is low; yet, when

* Account of the Ganges and Burrampooter Rivers, by Major Rennell, Phil. Trans. 1781.

it is periodically swollen by tropical rains, the velocity of the stream counteracts the tidal current, so that except very near the sea, the ebb and flow become insensible. During the flood season, therefore, the Ganges almost assumes the character of a river entering a lake or inland sea; the movements of the ocean being then subordinate to the force of the river, and only slightly disturbing its operations. The great gain of the delta in height and area takes place during the inundations; and, during other seasons of the year, the ocean makes reprisals, scouring out the channels, and sometimes devouring rich alluvial plains.

So great is the quantity of mud and sand poured by the Ganges into the gulf in the flood season, that the sea only recovers its transparency at the distance of sixty miles from the coast. The general slope, therefore, of the new strata must be extremely gradual. By the charts recently published, it appears that there is a gradual deepening from four to about sixty fathoms, as we proceed from the base of the delta to the distance of about one hundred miles into the Bay of Bengal. At some few points seventy, or even one hundred, fathoms are obtained at that distance.

One remarkable exception, however, occurs to the regularity of the shape of the bottom; for, opposite the middle of the delta, at the distance of thirty or forty miles from the coast, is a nearly circular space called the "swatch of no ground," about fifteen miles in diameter, where soundings of 100, and even 130, fathoms fail to reach the bottom. This phenomenon is the more extraordinary, since the depression occurs within five miles of the line of shoals; and not only do the waters charged with Gangetic sediment pass over it continually; but, during the monsoons, the sea, loaded

with mud and sand, is beaten back in that direction towards the delta. As the mud is known to extend for eighty miles farther into the gulf, we may be assured that, in the course of ages, the accumulation of strata, in "the swatch" has been of enormous thickness; and we seem entitled to deduce, from the present depth at the spot, that the original inequalities of the bottom of the Bay of Bengal were on a grand scale, and comparable to those of the main ocean.

Opposite the mouth of the Hoogly river, and immediately south of Sager Island, four miles from the nearest land of the delta, a new islet was formed about thirty years ago, called Edmonston Island, where there is a lighthouse. The islet has been for many years covered with vegetation and shrubs, but the whole surface was submerged for some hours during the late inundation of May, 1833, the light-keepers having only escaped by ascending into the lantern. By this flood the dimensions of the islet were considerably diminished. Although there is evidence of gain at some points, the general progress of the coast is very slow; for the tides, which rise from thirteen to sixteen feet, are actively employed in removing the alluvial matter, and diffusing it over a wide area.* The new strata consist entirely of sand and fine mud; such, at least, are the only materials which are exposed to view in regular beds on the

* It is stated in the chart published in the year 1825, by Captain Horsburgh, that the sands opposite the whole delta stretched between four and five miles farther south than they had done forty years previously; and this was taken as the measure of the progress of the delta itself, during the same period. But a more careful comparison of the ancient charts, during a recent survey, has proved that they were extremely incorrect in their latitudes, so that the advance of the sands and delta was greatly exaggerated.

banks of the numerous creeks. No substance so coarse as gravel occurs in any part of the delta, nor nearer the sea than 400 miles. It should be observed, however, that the superficial alluvial beds, which are thrown down rapidly from turbid waters during the floods, may be very distinct from those deposited at a greater distance from the shore, where crystalline precipitates, perhaps, are forming, on the evaporation of so great a surface, exposed to the rays of a tropical sun. The separation of sand and other matter, held in mechanical suspension, may take place where the waters are in motion; but mineral ingredients, held in chemical solution, would naturally be carried to a greater distance, where they may aid in the formation of corals and shells, and, in part, perhaps, become the cementing principle of rocky masses.

A well was sunk at Fort William, Calcutta, in the hope of obtaining water, through beds of adhesive clay, to the depth of 146 feet. A bed of yellow sand was then entered, and at the depth of 152 feet another stratum of clay.*

Islands formed and destroyed.—Major R. H. Colebrooke, in his account of the course of the Ganges relates examples of the rapid filling up of some of its branches, and the excavation of new channels, where the number of square miles of soil removed in a short time (the column of earth being 114 feet high) was truly astonishing. Forty square miles, or 25,600 acres are mentioned as having been carried away, in one place in the course of a few years.† The immense transportation of earthy matter by the Ganges and

* See India Gazette, June 9., 1831.

† Trans. of the Asiatic Society, vol. vii. p. 14.

Megna is proved by the great magnitude of the islands formed in their channels during a period far short of that of a man's life. Some of these, many miles in extent, have originated in large sand-banks thrown up round the points at the angular turning of the river, and afterwards insulated by breaches of the stream. Others, formed in the main channel, are caused by some obstruction at the bottom. A large tree, or a sunken boat, is sometimes sufficient to check the current, and cause a deposit of sand, which accumulates till it usurps a considerable portion of the channel. The river then borrows on each side to supply the deficiency in its bed, and the island is afterwards raised by fresh deposits during every flood. In the great gulf below Luckipour, formed by the united waters of the Ganges and Burrampooter (or Megna), some of the islands, says Rennell, rival in size and fertility the Isle of Wight. While the river is forming new islands in one part, it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the Tamarix Indica, and other shrubs, forming impenetrable thickets, where tigers, buffaloes, deer, and other wild animals, take shelter. It is easy, therefore, to perceive, that both animal and vegetable remains must continually be precipitated into the flood, and sometimes become imbedded in the sediment which subsides in the delta.

Two species of crocodiles, of distinct genera, abound in the Ganges and its tributary and contiguous waters; and Mr. H. T. Colebrooke informs me, that he has seen both kinds in places far inland, many hundred miles from the sea. The Gangetic crocodile, or Gavial (in correct orthography, Garial), is confined to the fresh water, but the common crocodile frequents

both fresh and salt; being much larger and fiercer in salt and brackish water. These animals swarm in the brackish water along the line of sand-banks where the advance of the delta is most rapid. Hundreds of them are seen together in the creeks of the delta, or basking in the sun on the shoals without. They will attack men and cattle, destroying the natives when bathing, and tame and wild animals which come to drink. "I have not unfrequently," says Mr. Colebrooke, "been witness to the horrid spectacle of a floating corpse seized by a crocodile with such avidity, that he half emerged above the water with his prey in his mouth." The geologist will not fail to observe how peculiarly the habits and distribution of these saurians expose them to become imbedded in the horizontal strata of fine mud, which are annually deposited over many hundred square miles in the Bay of Bengal. The inhabitants of the land, which happen to be drowned or thrown into the water, are usually devoured by these voracious reptiles; but we may suppose the remains of the saurians themselves to be continually entombed in the new formations.

Inundations.—It sometimes happens, at the season when the periodical flood is at its height, that a strong gale of wind, conspiring with a high spring-tide, checks the descending current of the river, and gives rise to most destructive inundations. From this cause, in the year 1763, the waters at Luckipour rose six feet above their ordinary level, and the inhabitants of a considerable district, with their houses and cattle, were totally swept away.

The population of all oceanic deltas are particularly exposed to suffer by such catastrophes, recurring at considerable intervals of time; and we may safely

assume, that such tragical events have happened again and again since the Gangetic delta was inhabited by man. If human experience and forethought cannot always guard against these calamities, still less can the inferior animals avoid them; and the monuments of such disastrous inundations must be looked for in great abundance in strata of all ages, if the surface of our planet has always been governed by the same laws. When we reflect on the general order and tranquillity that reigns in the rich and populous delta of Bengal, notwithstanding the havoc occasionally committed by the depredations of the ocean, we perceive how unnecessary it is to attribute the imbedding of successive races of animals in older strata to extraordinary energy in the causes of decay and reproduction in the infancy of our planet, or to those general catastrophes and sudden revolutions resorted to by some theorists.

Delta of the Mississippi. — As the delta of the Ganges may be considered a type of those formed on the borders of the ocean, it will be unnecessary to accumulate examples of others on a no less magnificent scale, as, for example, at the mouths of the Orinoco and Amazon. To these, however, I shall revert by and by, when treating of the agency of currents. The tides in the Mexican Gulf are so feeble, that the delta of the Mississippi has somewhat of an intermediate character between an oceanic and mediterranean delta. A long narrow tongue of land is protruded, consisting simply of the banks of the river, wearing precisely the same appearance as in the inland plains during the periodical inundations, when nothing appears above water but the higher part of the sloping glacis before described.* This tongue of land has advanced many

* Chapter II.

leagues since New Orleans was built. Great submarine deposits are also in progress, stretching far and wide over the bottom of the sea, which has become extremely shallow, not exceeding ten fathoms in depth. Opposite the mouth of the Mississippi large rafts of drift trees, brought down every spring, are matted together into a net-work many yards in thickness, and stretching over hundreds of square leagues.* They afterwards become covered over with a fine mud, on which other layers of trees are deposited the year following, until numerous alternations of earthy and vegetable matter are accumulated.

Alternation of deposits. — An observation of Darby, in regard to the strata composing part of this delta, deserves attention. In the steep banks of the Atchafalaya, an arm of the Mississippi before alluded to in our description of "the raft," the following section is observable at low water: — first, an upper stratum, consisting invariably of blueish clay, common to the banks of the Mississippi; below this a stratum of red ochreous earth, peculiar to Red River, under which the blue clay of the Mississippi again appears; and this arrangement is constant, proving, as that geographer remarks, that the waters of the Mississippi and the Red River occupied alternately, at some former periods, considerable tracts below their present point of union.† Such alternations are probably common in submarine spaces situated between two converging deltas; for, before the two rivers unite, there must almost always be a certain period when an intermediate tract will by turns be occupied and abandoned by the

* Captain Hall's Travels in North America, vol. iii. p. 338.— See also above, p. 271.

† Darby's Louisiana, p. 103.

waters of each stream; since it can rarely happen that the season of highest flood will precisely correspond in each. In the case of the Red River and Mississippi, which carry off the waters from countries placed under widely distant latitudes, an exact coincidence in the time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of sediment in river water.—Very few satisfactory experiments have as yet been made, to enable us to determine, with any degree of accuracy, the mean quantity of earthy matter discharged annually into the sea by some one of the principal rivers of the earth. Hartsoeker computed the Rhine to contain in suspension, when most flooded, one part in a hundred of mud in volume *; but it appears from two sets of experiments recently made by Mr. Leonard Horner, at Bonn, that $\frac{1}{16000}$th would have been a nearer approximation to the truth. † Sir George Staunton inferred from several observations, that the water of the Yellow River in China contained earthy matter in the proportion of one part to two hundred, and he calculated that it brought down in a single hour two million cubic feet of earth, or forty-eight million daily; so that, if the Yellow Sea be taken to be 120 feet deep, it would require seventy days for the river to convert an English square mile into firm land, and 24,000 years to turn the whole sea into terra firma, assuming it to be

* Comment. Bonon., vol. ii. part. i. p. 237.

† Edin. New Phil. Journ., Jan. 1835.

125,000 square miles in area.* Manfredi, the celebrated Italian hydrographer, conceived the average proportion of sediment in all the running water on the globe, which reached the sea, to be $\frac{1}{175}$, and he imagined that it would require a thousand years for the sediment carried down to raise the general level of the sea about one foot. Some writers, on the contrary, as De Maillet, have declared the most turbid waters to contain far less sediment than any of the above estimates would import. One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the delta of the Ganges. "A glass of water," he says, "taken out of this river when at its height, yields about one part in four of mud. No wonder, then," he adds, "that the subsiding waters should quickly form a stratum of earth, or that the delta should encroach on the sea!"†

There must certainly be some mistake, perhaps a misprint, in the statement in the Phil. Trans.; and some have conjectured that the learned hydrographer meant one part in four hundred of mud. In former editions of this work, I expressed my regret that so much inconsistency and contradiction should be found in the statements and speculations relative to this interesting subject; and I endeavoured to point out the high geological importance of reducing to arithmetical computation the aggregate amount of solid matter transported by certain large rivers to the sea. The deficiency of data has now been, in some degree, removed by the labours of the Rev. Mr. Everest, who has

* Staunton's Embassy to China, Lond. 1797, 4to. vol. ii. p. 408.
† Phil. Trans. 1781.

instituted a series of observations "On the earthy matter brought down by the Ganges" at Ghazipúr, above Calcutta. *

The first step to be made in all such calculations is to ascertain the average volume of water passing annually down the channel of a river. This might easily be accomplished if the breadth, depth, and velocity of a stream were constant and uniform throughout the year; but as all these conditions are liable to vary according to the seasons, the problem becomes extremely complex. In the Ganges, as in other rivers in hot climates, there are periodical inundations, during which by far the greatest part of the annual discharge takes place; and the most important point, therefore, to determine, is the mean breadth, depth, and velocity of the stream during this period.

Mr. Everest found that, in 1831, the number of cubic feet of water discharged by the Ganges per second was, during the

Rains, (4 months) - -	494,208
Winter, (5 months) - -	71,200
Hot weather, (3 months) -	36,330

so that we may state in round numbers, that 500,000 cubic feet flow down during the four months of the flood season, from June to September, and only 100,000 during the remaining eight months.

Having obtained the volume of water, we have next to inquire what is the proportion of solid matter con-

* Journ. of Asiatic Soc., No. 6. p. 238. June, 1832. See also Mr. Prinsep, Gleanings in Science, vol. iii. p. 185.

tained in it; and for this purpose, a definite quantity, as, for example, a quart, is taken from the river on different days, sometimes from the middle of the current, and sometimes nearer the banks. This water is then evaporated, the solid residuum weighed, and the mean quantity of sediment thus ascertained, throughout the rainy season. The same observations must then be repeated for the other portions of the year.

In computing the quantity of water, Mr. Everest made no allowance for the decreased velocity of the stream near the bottom, presuming that it is compensated by the increased weight of matter held in suspension there. Probably the amount of sediment is by no means exaggerated by this circumstance; but rather under-rated, as the heavier grains of sand, which can never rise into the higher parts of the stream, are drifted along the bottom.

Now the average quantity of solid matter suspended in the water during the rains was, by weight $\frac{1}{428}$th part; but, as the water is about one half the specific gravity of the dried mud, the solid matter discharged is $\frac{1}{856}$th part in bulk, or 577 cubic feet per second. This gives a total of 6,082,041,600 cubic feet for the discharge in the 122 days of the rain. The proportion of sediment in the waters at other seasons was comparatively insignificant, the total amount during the five winter months being only 247,881,600 cubic feet, and during the three months of hot weather, 38,154,240 cubic feet. The total annual discharge, then, would be 6,368,077,440 cubic feet.

In order to give some idea of the magnitude of this result, we will assume that the specific gravity of the dried mud is only one half that of granite (it would,

however, be more); in that case, the earthy matter discharged in a year would equal 3,184,038,720 cubic feet of granite. Now about 12½ cubic feet of granite weigh one ton; and it is computed that the great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 tons. The mass of matter, therefore, carried down annually, would, according to this estimate, more than equal in weight and bulk forty-two of the great Pyramids of Egypt, and that borne down in the four months of the rains would equal forty pyramids. But if, without any conjecture as to what may have been the specific gravity of the mud, we attend merely to the weight of solid matter actually proved by Mr. Everest to have been contained in the water, we find that the number of tons weight which passed down in the 122 days of the rainy season was 339,413,760, which would give the weight of fifty-six pyramids and a half; and in the whole year 355,361,464 tons, or nearly the weight of sixty pyramids.

The base of the great Pyramid of Egypt covers eleven acres, and its perpendicular height is about five hundred feet. It is scarcely possible to present any picture to the mind which will convey an adequate conception of the mighty scale of this operation, so tranquilly and almost insensibly carried on by the Ganges, as it glides through its alluvial plain. It may, however, be stated, that if a fleet of more than eighty Indiamen, each freighted with about 1400 tons weight of mud, were to sail down the river every hour of every day and night for four months continuously, they would only transport from the higher country to the sea a mass of solid matter equal to that borne down by the Ganges in the flood season. Or the exertions

of a fleet of about 2000 such ships going down daily with the same burden, and discharging it into the gulf, would be no more than equivalent to the operations of the great river. Yet, in addition to this, it is probable that the Burrampooter conveys annually as much solid matter to the sea as the Ganges.

The most voluminous current of lava which has flowed from Etna within historical times was that of 1669. Ferrara, after correcting Borrelli's estimate, calculated the quantity of cubic yards of lava in this current at 140,000,000. Now, this would not equal in bulk one fifth of the sedimentary matter which is carried down in a single year by the Ganges, according to the estimate above explained; so that it would require five grand eruptions of Etna to transfer a mass of lava from the subterranean regions to the surface, equal in volume to the mud carried down to the sea in one year by a single river in Bengal.

Grouping of Strata in Deltas.—The changes which have taken place in deltas, even since the times of history, may suggest many important considerations in regard to the manner in which subaqueous sediment is distributed. Notwithstanding frequent exceptions, arising from the interference of a variety of causes, there are some general laws of arrangement which must evidently hold good in almost all the lakes and seas now filling up. If a lake, for example, be encircled on two sides by lofty mountains, receiving from them many rivers and torrents of different sizes, and if it be bounded on the other sides, where the surplus waters issue, by a comparatively low country, it is not difficult to define some of the leading geological features which must characterize the lacustrine formation, when this basin shall have been gradually con-

verted into dry land by the influx of sediment. The strata would be divisible into two principal groups: the *older* comprising those deposits which originated on the side adjoining the mountains, where numerous deltas first began to form; and the *newer* group consisting of beds deposited in the more central parts of the basin, and towards the side farthest from the mountains. The following characters would form the principal marks of distinction between the strata in each series. The more ancient system would be composed, for the most part, of coarser materials, containing many beds of pebbles and sand, often of great thickness, and sometimes dipping at a considerable angle. These, with associated beds of finer ingredients, would, if traced round the borders of the basin, be seen to vary greatly in colour and mineral composition, and would also be very irregular in thickness. The beds, on the contrary, in the newer group, would consist of finer particles, and would be horizontal, or very slightly inclined. Their colour and mineral composition would be very homogeneous throughout large areas, and would differ from almost all the separate beds in the older series.

The following causes would produce the diversity here alluded to between the two great members of such lacustrine formations:—When the rivers and torrents first reach the edge of the lake, the detritus washed down by them from the adjoining heights sinks at once into deep water, all the heavier pebbles and sand subsiding near the shore. The finer mud is carried somewhat farther out, but not to the distance of many miles, for the greater part may be seen, as, for example, where the Rhone enters the Lake of Geneva, to fall down in clouds to the bottom not far from the

river's mouth. Thus alluvial tracts are soon formed at the mouths of every torrent and river, and many of these in the course of ages become of considerable extent. Pebbles and sand are then transported farther from the mountains; but in their passage they decrease in size by attrition, and are in part converted into mud and sand. At length some of the numerous deltas which are all directed towards a common centre approach near to each other — those of adjoining torrents become united, and each is merged, in its turn, in the delta of the largest river, which advances most rapidly into the lake, and renders all the minor streams, one after the other, its tributaries. The various mineral ingredients of all are thus blended together into one homogeneous mixture, and the sediment is poured out from a common channel into the lake.

As the average size of the transported particles decreases, while the force and volume of the current augments, the newer deposits are diffused continually over a wider area, and are consequently more horizontal than the older. When at first there were many independent deltas near the borders of the basin, their separate deposits differed entirely from each other; one may have been charged, like the Arve where it joins the Rhone, with white sand, and sediment derived from granite — another may have been black, like many streams in the Tyrol, flowing from the waste of decomposing rocks of dark slate — a third may have been coloured by ochreous sediment, like the Red River in Louisiana — a fourth, like the Elsa in Tuscany, may have held much carbonate of lime in solution. At first they would each form distinct deposits of sand, gravel, limestone, marl, or other materials; but after their junction new chemical combinations

and a distinct colour would be the result, and the particles, having been conveyed ten, twenty, or a greater number of miles over alluvial plains, would become finer.

In deltas where the causes are more complicated, and where tides and currents partially interfere, the above description would only be applicable, with certain modifications; but if a series of earthquakes accompany the growth of a delta, and change the levels of the land from time to time, as in the region where the Indus now enters the sea, and others hereafter to be mentioned, the phenomena will then depart still more widely from the ordinary type.

Convergence of Deltas. — If we possessed an accurate series of maps of the Adriatic for many thousand years, our retrospect would, without doubt, carry us gradually back to the time when the number of rivers descending from the mountains into that gulf by independent deltas was far greater in number. The deltas of the Po and the Adige, for instance, would separate themselves within the *recent* era, as, in all probability, would those of the Isonzo and the Torre. If, on the other hand, we speculate on future changes, we may anticipate the period when the number of deltas will greatly diminish; for the Po cannot continue to encroach at the rate of a mile in a hundred years, and other rivers to gain as much in six or seven centuries upon the shallow gulf, without new junctions occurring from time to time, so that Eridanus, "the king of rivers," will continually boast a greater number of tributaries. The Ganges and the Burrampooter have probably become confluent within the historical era; and the date of the junction of the Red River and the Mississippi would, in all likelihood, have been

known if America had not been so recently discovered. The union of the Tigris and the Euphrates must undoubtedly have been one of the modern geographical changes on our earth, and similar remarks might be extended to many other regions.

When the deltas of rivers, having many mouths, converge, a partial union at first takes place by the confluence of some one or more of their arms; but it is not until the main trunks are connected above the head of the common delta, that a complete intermixture of their joint waters and sediment takes place. The union, therefore, of the Po and Adige, and of the Ganges and Burrampooter, is still incomplete. If we reflect on the geographical extent of surface drained by rivers such as now enter the Bay of Bengal, and then consider how complete the blending together of the greater part of their transported matter has already become, and throughout how vast a delta it is spread by numerous arms, we no longer feel so much surprise at the area occupied by some ancient formations of homogeneous mineral composition. But our surprise will be still further lessened when we afterwards inquire into the action of tides and currents, in disseminating sediment.*

Formation of Conglomerates. — Along the base of the Maritime Alps, between Toulon and Genoa, the rivers, with few exceptions, are now forming strata of conglomerate and sand. Their channels are often several miles in breadth, some of them being dry, and the rest easily forded for nearly eight months in the year, whereas during the melting of the snow they are swollen, and a great transportation of mud and

* See Chap. viii.

pebbles takes place. In order to keep open the main road from France to Italy, now carried along the sea-coast, it is necessary to remove annually great masses of shingle brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made by the deltas of minor rivers on this coast need not surprise us, when we recollect that there is sometimes a depth of two thousand feet at a few hundred yards from the beach, as near Nice. Similar observations might be made respecting a large proportion of the rivers in Sicily, and, among others, respecting that which, immediately north of the port of Messina, hurries annually vast masses of granitic pebbles into the sea.

Causes of Stratification in Deltas.—That the matter carried by rivers into seas and lakes is not thrown in confused and promiscuous heaps, but is spread out far and wide along the bottom, is well ascertained; and that it must for the most part be divided into distinct strata, may in part be inferred where it cannot be proved by observation. The horizontal arrangement of the strata, when laid open to the depth of twenty or thirty feet in the deltas of the Ganges, Indus, and Mississippi, is alluded to by many writers; and the same disposition is well known to obtain in all modern deposits of lakes and estuaries.

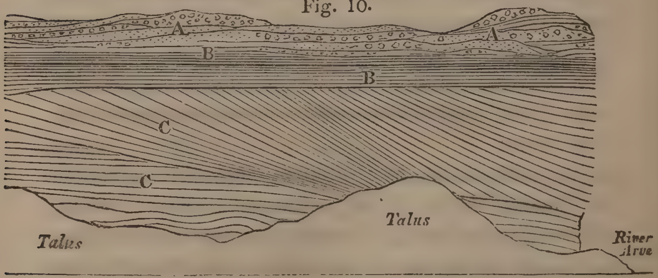
Natural divisions are often occasioned by the interval of time which separates annually the deposition of matter during the periodical rains, or melting of the snow upon the mountains. The deposit of each year may acquire some degree of consistency before that of the succeeding year is superimposed. A variety of cir-

cumstances also give rise annually, or sometimes from day to day, to slight variations in colour, fineness of the particles, and other characters, by which alternations of strata distinct in texture, and mineral ingredients, must be produced. Thus, for example, at one period of the year, drift wood may be carried down, and at another mud, as was before stated to be the case in the delta of the Mississippi; or at one time, when the volume and velocity of the stream are greatest, pebbles and sand may be spread over a certain area, over which, when the waters are low, fine matter or chemical precipitates are formed. During inundations, the current of fresh water often repels the sea for many miles; but when the river is low, salt water again occupies the same space. When two deltas are converging, the intermediate space is often, for reasons before explained, alternately the receptacle of different sediments derived from the converging streams. The one is, perhaps, charged with calcareous, the other with argillaceous matter; or one sweeps down sand and pebbles, the other impalpable mud. These differences may be repeated, with considerable regularity, until a thickness of hundreds of feet of alternating beds is accumulated. The multiplication, also, of shells and corals in particular spots, must give rise occasionally to lines of separation, and divide a mass which might otherwise be homogeneous into distinct strata.

An examination of the shell marl now forming in the Scotch lakes, or the sediment termed "warp," which subsides from the muddy water of the Humber, and other rivers, shews that recent deposits are often composed of a great number of extremely thin layers, either even or slightly undulating, and preserving a

general parallelism to the planes of stratification. Sometimes, however, the laminæ in modern strata are disposed diagonally at a considerable angle, which appears to take place where there are conflicting movements in the waters. In January, 1829, I visited, in company with Professor L. A. Necker, of Geneva, the confluence of the Rhone and Arve, when those rivers were very low, and were cutting channels through the vast heaps of debris thrown down from the waters of the Arve, in the preceding spring. One of the sandbanks which had formed, in the spring of 1828, where the opposing currents of the two rivers neutralized each other, and caused a retardation in the motion, had been undermined; and the following is an exact representation of the arrangement of laminæ exposed in a vertical section. The length of the portion here seen is about twelve feet, and the height five. The strata A A consist of irregular alternations of pebbles and sand in undulating beds: below these are seams of very fine sand B B, some as thin as paper, others about a quarter of an inch thick. The strata C C are

Fig. 10.



Section on the banks of the Arve at its confluence with the Rhone, showing the stratification of deposits where currents meet.

composed of layers of fine greenish-gray sand, as thin as paper. Some of the inclined beds will be seen to be thicker at their upper, others at their lower extremity, the inclination of some being very considerable. These layers must have accumulated one on the other by lateral apposition, probably when one of the rivers was very gradually increasing or diminishing in velocity, so that the point of greatest retardation caused by their conflicting currents shifted slowly, allowing the sediment to be thrown down in successive layers on a sloping bank. The same phenomenon is exhibited in older strata of all ages; and when they are treated of, I shall endeavour more fully to illustrate the origin of such a structure.

Constant interchange of land and sea.—I may here conclude my remarks on deltas, observing that, imperfect as is our information of the changes which they have undergone within the last three thousand years, they are sufficient to shew how constant an interchange of sea and land is taking place on the face of our globe. In the Mediterranean alone, many flourishing inland towns, and a still greater number of ports, now stand where the sea rolled its waves since the era of the early civilization of Europe. If we could compare with equal accuracy the ancient and actual state of all the islands and continents, we should probably discover that millions of our race are now supported by lands situated where deep seas prevailed in earlier ages. In many districts not yet occupied by man, land animals and forests now abound where ships once sailed, and on the other hand, we shall find, on inquiry, that inroads of the ocean have been no less considerable. When to these revolutions, produced

by aqueous causes, we add analogous changes wrought by igneous agency, we shall, perhaps, acknowledge the justice of the conclusion of Aristotle, who declared that the whole land and sea on our globe periodically changed places.*

* See above, Book i. p. 21.

GLOSSARY

OF GEOLOGICAL AND OTHER SCIENTIFIC TERMS USED IN THIS WORK.

ACEPHALOUS. The Acephala are that division of molluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of animals with bivalve shells, and a few which are devoid of shells. *Etym.*, α, *a*, without, and κεφαλη, *cephale*, the head.

ADIPOCIRE. A substance apparently intermediate between fat and wax, into which dead animal matter is converted when buried in the earth, and in a certain stage of decomposition. *Etym.*, *adeps*, fat, and *cera*, wax.

ALEMBIC. An apparatus for distilling.

ALGÆ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *alga*, sea-weed.

ALLUVIAL. The adjective of alluvium, which see.

ALLUVION. Synonymous with alluvium, which see.

ALLUVIUM. Earth, sand, gravel, stones, and other transported matter which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *alluo*, to wash upon. For a further explanation of the term, as used in this work, see Vol. III. p. 218., and Vol. IV. p. 57.

ALUM-STONE, ALUMEN, ALUMINOUS. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the alluminous earth

of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

AMMONITE. An extinct and very numerous genus of the order of molluscous animals called Cephalopoda, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not been seen in the tertiary beds. They are named from their resemblance to the horns on the statues of Jupiter Ammon.

AMORPHOUS. Bodies devoid of regular form. *Etym.*, α, *a*, without, and μορφη, *morphe*, form.

AMYGDALOID. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, αμυγδαλα, *amygdala*, an almond.

ANALCIME. A simple mineral of the Zeolite family, also called Cubizite, of frequent occurrence in the trap-rocks.

ANALOGUE. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil-shell is the analogue of the latter.

ANOPLOTHERE, ANOPLOTHERIUM. A fossil extinct quadruped belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defence, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, ανοπλος, *anoplos*, unarmed, and θηριον, *therion*, a wild beast.

ANTAGONIST POWERS. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

ANTENNÆ. The articulated horns with which the heads of insects are invariably furnished.

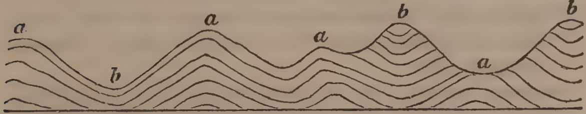
ANTHRACITE. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, ανθραξ, *anthrax*, coal.

ANTHRACOTHERIUM. A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were found in lignite and coal of the tertiary strata. *Etym.*, ανθραξ, *anthrax*, coal, and θηριον, *therion*, wild beast.

ANTHROPOMORPHOUS. Having a form resembling the human. *Etym.*, ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form.

ANTICLINAL AXIS. If a range of hills, or a valley, be composed of strata, which on the two sides dip in opposite directions, the imaginary line that lies between them, towards which the strata on each side rise, is called the anticlinal axis. In a row of houses with steep roofs facing the south, the slates represent inclined strata dipping north and south, and the ridge is an east and west anticlinal axis. In the accompanying diagram, *a*, *a* are the anticlinal, and *b*, *b* the synclinal lines. *Etym.*, αντι, *anti*, against, and κλινω, *clino*, to incline.

Fig. 11.



ANTISEPTIC. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be antiseptic. *Etym.*, αντι, *against*, and σηπω, *sepo*, to putrefy.

ARENACEOUS. Sandy. *Etym.*, *arena*, sand.

ARGILLACEOUS. Clayey, composed of clay. *Etym.*, *argilla*, clay.

ARRAGONITE. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

AUGITE. A simple mineral of a dark green, or black colour, which forms a constituent part of many varieties of volcanic rocks.

AVALANCHES. Masses of snow which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

BASALT. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides, called basaltic columns. Remarkable examples of this kind

are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Æthiopian word signifying iron. The rock often contains much iron.

"Basin" of Paris, "Basin" of London. Deposits lying in a hollow or trough, formed of older rocks; sometimes used in geology almost synonymously with "formations," to express the deposits lying in a certain cavity or depression in older rocks.

Belemnite. An extinct genus of the order of molluscous animals called Cephalopoda, having a long, straight, and chambered conical shell. *Etym.*, *βελεμνον*, *belemnon*, a dart.

Bitumen. Mineral pitch, of which the tar-like substance which is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *bitumen*, pitch.

Bituminous Shale. An argillaceous shale, much impregnated with bitumen, which is very common in the coal measures.

Blende. A metallic ore, a compound of the metal zinc with sulphur. It is often found in brown shining crystals; hence its name among the German miners, from the word *blenden*, to dazzle.

Bluffs. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

Botryoidal. Resembling a bunch of grapes. *Etym.*, *βοτρυς*, *botrys*, a bunch of grapes, and *ειδος*, *eidos*, form.

Boulders. A provincial term for large rounded blocks of stone lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

Breccia. A rock composed of angular fragments connected together by lime or other mineral substance. An Italian term.

Calc Sinter. A German name for the deposits from springs holding carbonate of lime in solution — petrifying springs. *Etym.*, *kalk*, lime, *sintern*, to drop.

Calcaire Grossier. An extensive stratum, or rather series of strata, found in the Paris Basin, belonging to the Eocene tertiary period. See Table I. E, Vol. IV. p.309. *Etym.*, *calcaire*, limestone, and *grossier*, coarse.

Calcareous Rock. Limestone. *Etym.*, *calx*, lime.

Calcareous Spar. Crystallized carbonate of lime.

Calcedony. A siliceous simple mineral, uncrystallized. Agates are partly composed of calcedony.

Carbon. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *carbo*, coal.

Carbonate of Lime. Lime combines with great avidity with carbonic acid, a gaseous acid only obtained fluid when united with water,—and all combinations of it with other substances are called *Carbonates*. All limestones are carbonates of lime, and quick lime is obtained by driving off the carbonic acid by heat.

Carbonated Springs. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries; and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

Carbonic Acid Gas. A natural gas which often issues from the ground, especially in volcanic countries. *Etym.*, *carbo*, coal, because the gas is obtained by the slow burning of charcoal.

Carboniferous. A term usually applied, in a technical sense, to an ancient group of secondary strata, (see Table I. M, Vol. IV. p. 312.); but any bed containing coal may be said to be carboniferous. *Etym.*, *carbo*, coal, and *fero*, to bear.

Cataclysm. A deluge. *Etym.*, *κατακλυζω*, *catacluzo*, to deluge.

Cephalopoda. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, *κεφαλη*, *cephale*, head, and *ποδα*, *poda*, feet.

Cetacea. An order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and narwal are examples. *Etym.*, *cete*, whale.

Chalk. A white earthy limestone, the uppermost of the secondary series of strata. See Table I. F, Vol. IV., p. 309.

Chert. A siliceous mineral, nearly allied to calcedony and flint,

but less homogeneous and simple in texture. A gradual passage from chert to limestone is not uncommon.

Chloritic Sand. Sand coloured green by an admixture of the simple mineral chlorite. *Etym.*, χλωρος, *chloros*, green.

Cleavage. Certain rocks, usually called slate-rocks, may be cleaved into an indefinite number of thin laminæ which are parallel to each other, but which are generally not parallel to the planes of the true strata or layers of deposition. The planes of cleavage, therefore, are distinguishable from those of stratification; and they also differ from joints, which are fissures or lines of parting, at definite distances, and often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms are joints. The masses of rock included between joints cannot be cleaved into an indefinite number of laminæ or slates, having their planes of cleavage parallel to the joints. See first part of Chap. xxvii. Book iv.

Clinkstone, called also phonolite, a felspathic rock of the Trap family, usually fissile. It is sonorous when struck with a hammer, whence its name.

Coal Formation. This term is generally understood to mean the same as the Coal Measures. See Table I., M, Vol. IV. p. 312. There are, however, "coal formations" in all the geological periods, wherever any of the varieties of coal forms a principal constituent part of a group of strata.

Coleoptera. An order of insects (Beetles) which have four wings, the upper pair being crustaceous and forming a shield. *Etym.*, κολεος, *coleos*, a sheath, and πτερον, *pteron*, a wing.

Conformable. When the planes of one set of strata are generally parallel to those of another set which are in contact, they are said to be conformable. Thus the set *a*, *b*, Fig. 115., Vol. IV. p. 133., rest conformably on the inferior set *c*, *d*; but *c*, *d* rest unconformably on E.

Congeners. Species which belong to the same genus.

Conglomerate or puddingstone. Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a siliceous, calcareous, or argillaceous nature. *Etym.*, *con*, together, *glomero*, to heap.

Coniferæ. An order of plants which, like the fir and pine, bear

cones or tops in which the seeds are contained. *Etym.*, *conus*, cone, and *fero*, to bear.

COOMB. A provincial name in different parts of England for a valley on the declivity of a hill, and which is generally without water.

CORNBRASH. A rubbly limestone, forming a soil extensively cultivated in Wiltshire for the growth of corn. It is a provincial term adopted by Smith. Brash is derived from brecan, Saxon, to break. See Table I. H, Vol. IV. p. 310.

CORNSTONE. A provincial name for a red limestone, forming a subordinate bed in the Old Red Sandstone group.

COSMOGONY, COSMOLOGY. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

CRAG. A provincial name in Norfolk and Suffolk for a deposit, usually of gravel, belonging to the Older Pliocene period. See Table I., C, Vol. IV. p. 309.

CRATER. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *crater*, a great cup or bowl.

CRETACEOUS. Belonging to chalk. *Etym.*, *creta*, chalk.

CROP OUT. A miner's or mineral surveyor's term, to express the rising up or exposure at the surface of a stratum or series of strata.

CRUST OF THE EARTH. See Earth's crust.

CRUSTACEA. Animals having a shelly coating or crust which they cast periodically. Crabs, shrimps, and lobsters, are examples.

CRYPTOGAMIC. A name applied to a class of plants, such as ferns, mosses, sea-weeds, and fungi, in which the fructification or organs of reproduction are concealed. *Etym.*, κρυπτος, *kryptos*, concealed, and γαμος, *gamos*, marriage.

CRYSTALS. Simple minerals are frequently found in regular forms, with facets like the drops of cut glass of chandeliers. Quartz being often met with in rocks in such forms, and beautifully transparent like ice, was called *rock-crystal*, κρυσταλλος, *crystallos*, being Greek for ice. Hence the regular *forms* of other minerals are called crystals, whether they be clear or opake.

CRYSTALLIZED. A mineral which is found in regular forms or crystals is said to be crystallized.

CRYSTALLINE. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystalline* texture. Sugar-candy and calcareous spar are crystallized.

CYCADEÆ. An order of plants which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds by botanists, which spreads in a circle. The term is derived from κυκας, *cycas*, a name applied by the ancient Greek naturalist Theophrastus to a palm.

CYPERACEÆ. A tribe of plants answering to the English sedges; they are distinguished from grasses by their stems being solid, and generally triangular, instead of being hollow and round. Together with *gramineæ* they constitute what writers on botanical geography often call *glumaceæ*.

DEBACLE. A great rush of waters, which, breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *débacler*, French, to unbar, to break up as a river does at the cessation of a long-continued frost.

DELTA. When a great river, before it enters the sea, divides into separate streams, they often diverge and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, was first called, in the case of the Nile, a delta, from its resemblance to the letter of the Greek alphabet which goes by that name Δ. Geologists apply the term to alluvial land formed by a river at its mouth, without reference to its precise shape.

DENUDATION. The carrying away by the action of running water of a portion of the solid materials of the land, by which inferior rocks are laid bare. *Etym.*, *denudo*, to lay bare.

DESICCATION. The act of drying up. *Etym.*, *desicco*, to dry up.

DEOXIDIZED, DEOXIDATED. Deprived of oxygen. Disunited from oxygen.

DIAGONAL STRATIFICATION. For an explanation of this term, see Vol. IV. p. 91.

Dicotyledonous. A grand division of the vegetable kingdom, founded on the plant having two *cotyledons* or seed-lobes. *Etym.*, *δις*, *dis*, double, and *κοτυληδον*, cotyledon.

Dikes. When a mass of the unstratified or igneous rocks, such as granite, trap, and lava, appears as if injected into a great rent in the stratified rocks, cutting across the strata, it forms a dike; and as they are sometimes seen running along the ground, and projecting, like a wall, from the softer strata on both sides of them having wasted away, they are called in the north of England and in Scotland *dikes*, the provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads.

Diluvium. Those accumulations of gravel and loose materials which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

Dip. When a stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass, and the angle it makes with the horizon is called the angle of dip or inclination.

Diptera. An order of insects, comprising those which have only two wings. *Etym.*, *δις*, *dis*, double, and *πτερον*, *pteron*, wing.

Dolerite. One of the varieties of the trap-rocks, composed of augite and felspar.

Dolomite. A crystalline limestone, containing magnesia as a constituent part. Named after the French geologist Dolomieu.

Dunes. Low hills of blown sand that skirt the shores of Holland, England, Spain, and other countries.

Earth's Crust. Such superficial parts of our planet as are accessible to human observation.

Elytra. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles. They cover the body and protect the true membranous wing. *Etym.*, *ελυτρον*, *elytron*, a sheath.

Eocene. See explanation of this word, Vol. III. p. 393.

Escarpment, the abrupt face of a ridge of high land. *Etym.*, *escarper*, French, to cut steep.

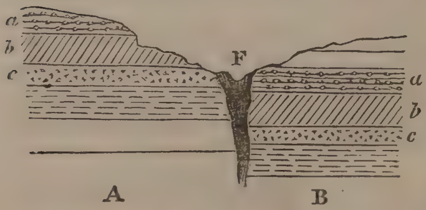
Estuaries. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym.*, *æstus*, the tide.

Experimentum Crucis. A decisive experiment, so called because, like a cross or direction post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture whereby the nature of the thing is extorted, as it were, by violence.

Exuviæ. Properly speaking, the transient parts of certain animals which they put off or lay down to assume new ones, as serpents and caterpillars shift their skins; but in geology it refers not only to the cast-off coverings of animals, but to fossil shells and other remains which animals have left in the strata of the earth. *Etym.*, *exuere*, to put off or divest.

Faluns. A French provincial name for some tertiary strata abounding in shells in Touraine, which resemble in lithological characters the "crag" of Norfolk and Suffolk.

Fault, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c.



The strata *a*, *b*, *c*, &c., must at one time have been continuous; but a fracture having taken place at the fault F, either by the upheaving of the portion A, or the sinking of the portion B, the strata were so displaced, that the bed *a* in B is many feet lower than the same bed *a* in the portion A.

Fauna. The various kinds of animals peculiar to a country constitute its Fauna, as the various kinds of plants constitute

its Flora. The term is derived from the Fauni, or rural, deities in Roman Mythology.

Felspar. A simple mineral, which, next to quartz, constitutes the chief material of rocks. The white angular portions in granite are felspar. This mineral always contains some alkali in its composition. In *common felspar* the alkali is potash; in another variety, called Albite or Cleavlandite, it is soda. Glassy felspar is a term applied when the crystals have a considerable degree of transparency. *Compact* felspar is a name of more vague signification. The substance so called appears to contain both potash and soda.

Felspathic. Of or belonging to felspar.

Ferruginous. Any thing containing iron. *Etym.*, *ferrum*, iron.

Floetz Rocks. A German term applied to the secondary strata by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds. *Etym.*, *flötz*, a layer or stratum.

Flora. The various kinds of trees and plants found in any country constitute the flora of that country in the language of botanists.

Fluviatile. Belonging to a river. *Etym.*, *fluvius*, a river.

Formation. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

Fossil. All minerals were once called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth. *Etym.*, *fossilis*, any thing that may be dug out of the earth.

Fossiliferous. Containing organic remains.

Galena. A metallic ore, a compound of lead and sulphur. It has often the appearance of highly polished lead. *Etym.*, *γαλεω*, *galeo*, to shine.

Garnet. A simple mineral, generally of a deep red colour, crystallized; most commonly met with in mica slate, but also in granite and other igneous rocks.

Gasteropods. A division of the Testacea in which, as in the limpet, the foot is attached to the body. *Etym.*, *γαστηρ*, belly and *ποδα*, *poda*, feet.

Gault. A provincial name in the east of England for a series

of beds of clay and marl, the geological position of which is between the upper and lower green-sand. See Table I. F, Vol. IV. p. 309.

GEM, or GEMMULE, from the Latin *gemma*, a bud. The term, applied to zoophytes, means a young animal not confined within an envelope or egg.

GEOLOGY, GEOGNOSY. Both mean the same thing; but, with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth *geognosy* (*Etym.*, *γεα*, *gea*, earth, and *γινωσκω*, *ginosco*, to know), and our theoretical speculations as to its formation *geology* (*Etym.*, *γεα*, and *λογος*, *logos*, a discourse).

GLACIER. Vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym.*, *glace*, French for ice.

GLACIS. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

GNEISS. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica and a laminated texture. The word is a German miner's term.

GRAMINEÆ. The order of plants to which grasses belong. *Etym.*, *gramen*, grass.

GRANITE. An unstratified or igneous rock, generally found inferior to or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is usually composed of three simple minerals, felspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets, afford good examples of the most common varieties of granite.

GREENSAND. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. See Table I. F, Vol. IV. p. 309. The name is given to these beds because they often, but not always, contain an abundance of green earth or chlorite scattered through the substance of the sandstone, limestone, &c. See Vol. IV. p. 284.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREYWACKÉ. *Grauwacke*, a German name, generally adopted by geologists for the lowest members of the secondary strata. O, Table I. Vol. IV. p. 313.; see also Vol. IV. p. 304. The rock is very often of a grey colour, hence the name, *grau*, being German for grey, and *wacke* being a provincial miner's term.

GRIT. A provincial name for a coarse-grained sandstone.

GYPSUM. A mineral composed of lime and sulphuric acid, hence called also *sulphate of lime*. Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abundantly near Paris, that plaster of Paris is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation is unknown.

GYPSEOUS, of or belonging to gypsum.

GYROGONITES. Bodies found in fresh-water deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of fresh-water plants of the genus *chara*. See Vol. III. p. 283. *Etym.*, γυρος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

HEMIPTERA. An order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membranous at the apex, ἥμισυ, *hemisu*, half, and πτερον, *pteron*, wing.

HORNBLENDE. A simple mineral of a dark green or black colour, which enters largely into the composition of several varieties of the trap rocks.

HORNSTONE. A siliceous mineral substance, sometimes approaching nearly to flint, or common quartz. It has a conchoidal fracture, and is infusible, which distinguishes it from compact felspar.

HUMERUS. The bone of the upper arm.

HYDROPHYTES. Plants which grow in water. *Etym.*, ὕδωρ, *hydor*, water, and φυτον, *phyton*, plant.

HYPOGENE ROCKS. For an explanation of this term, see Vol. IV. p. 385.

INCANDESCENT. White hot — having a more intense degree of heat than red heat.

ICEBERG. Great masses of ice, often the size of hills, which float in the polar and adjacent seas. *Etym.*, ice, and *berg*, German for hill.

ICHTHYOSAURUS. A gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.*, *ιχθυς*, *ichthus*, a fish, and *σαυρα*, *saura*, a lizard.

INDUCTION. A consequence, inference, or general principle drawn from a number of particular facts, or phenomena. The inductive philosophy, says Mr. Whewell, has been rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications.

INFUSORY ANIMALCULES. Minute living creatures found in many *infusions;* and the term *infusori* has been given to all such animalcules, whether found in infusions or in stagnant water, vinegar, &c.

INSPISSATED. Thickened. *Etym.*, *spissus*, thick.

INVERTEBRATED ANIMALS. Animals which are not furnished with a back-bone. For a further explanation, see "Vertebrated Animals."

ISOTHERMAL. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from *ισος*, *isos*, equal, and *θερμη*, *therme*, heat.

JOINTS, JOINTED STRUCTURE. See "Cleavage."

JURA LIMESTONE. The limestones belonging to the Oolitic Group (see Table I. H, Vol. IV. p. 310.) constitute the chief part of the mountains of the Jura, between France and Switzerland, and hence the geologists of the Continent have given the name to the group.

KIMMERIDGE CLAY. A thick bed of clay, constituting a member of the Oolite Group. See Table I. H, Vol. IV. p. 310. So called because it is found well developed at Kimmeridge in the isle of Purbeck, Dorsetshire.

Lacustrine. Belonging to a lake. *Etym.*, *lacus*, a lake.

Lamantine. A living species of the herbivorous cetacea or whale tribe, which inhabits the mouths of rivers on the coasts of Africa and South America: the sea-cow.

Lamelliferous. Having a structure consisting of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

Laminæ. Latin for plates; used in geology, for the smaller layers of which a stratum is frequently composed.

Landslip. A portion of land that has slid down in consequence of disturbance by an earthquake, or from being undermined by water washing away the lower beds which supported it.

Lapidification — Lapidifying process. Conversion into stone. *Etym.*, *lapis*, stone, and *fio*, to make.

Lapilli. Small volcanic cinders. *Lapillus*, a little stone.

Lava. The stone which flows in a melted state from a volcano.

Leucite. A simple mineral found in volcanic rocks, crystallized, and of a white colour. *Etym.*, λευκος, *leucos*, white.

Lias. A provincial name, adopted in scientific language, for a particular kind of limestone, which, being characterized together with its associated beds, by peculiar fossils, forms a particular group of the secondary strata. See Table I. Vol. IV. p. 311.

Ligniperdous. A term applied to insects which destroy wood. *Etym.*, *lignum*, wood, and *perdo*, to destroy.

Lignite. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

Lithodomi. Molluscous animals which form holes in solid rocks, in which they lodge themselves. The holes are not perforated mechanically, but the rock appears to be dissolved. *Etym.*, λιθος, *lithos*, stone, and δεμω, *demo*, to build.

Lithogenous Polyps. Animals which form coral.

Lithographic Stone. A slaty compact limestone, of a yellowish colour and fine grain, used in lithography, which is the art of drawing upon and printing from stone. *Etym.*, λιθος, *lithos*, stone, and γραφω, *grapho*, to write.

Lithoidal. Having a stony structure.

Lithological. A term expressing the stony structure or character of a mineral mass. We speak of the lithological character

of a stratum as distinguished from its zoological character. *Etym.*, λιθος, *lithos*, stone, and λογος, *logos*, discourse.

LITHOPHAGI. Molluscous animals which form holes in solid stones. See "Lithodomi." *Etym.*, λιθος, *lithos*, stone, and φαγειν, *phagein*, to eat.

LITHOPHYTES. The animals which form stone-coral.

LITTORAL. Belonging to the shore. *Etym.*, *littus*, the shore.

LOAM. A mixture of sand and clay.

LOPHIODON. A genus of extinct quadrupeds, allied to the Tapir, named from eminences on the teeth.

LYCOPODIACEÆ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses, generally found in mountainous heaths in the north of England.

LYDIAN STONE. A kind of quartz or flint, allied to hornstone, but of a greyish black colour.

MACIGNO. In Italy this term has been applied to a siliceous sandstone sometimes containing calcareous grains, mica, &c.

MADREPORE. A genus of corals, but generally applied to all the corals distinguished by superficial star-shaped cavities. There are several fossil species.

MAGNESIAN LIMESTONE. An extensive series of beds, the geological position of which is immediately above the coal-measures; so called because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part. See Table I. L, Vol. IV. p. 312.

MAMMIFEROUS. Mammifers. Animals which give suck to their young. To this class all the warm-blooded quadrupeds, and the cetacea, or whales, belong. *Etym.*, *mamma*, a breast, *fero*, to bear.

MAMMILLARY. A surface which is studded over with rounded projections. *Etym.*, *mammilla*, a little breast or pap.

MAMMOTH. An extinct species of the elephant (*E. primigenius*), of which the fossil bones are frequently met with in various countries. The name is of Tartar origin, and is used in Siberia for animals that burrow under ground.

MANATI. One of the cetacea, the sea-cow or lamantine (*Trichechus manatus*, Lin.)

MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.

MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young. The kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.

MASTODON. A genus of fossil extinct quadrupeds allied to the elephants; so called from the form of the hind teeth or grinders, which have their surface covered with conical mammillary crests. *Etm.*, *μαστος*, *mastos*, pap, and *οδων*, *odon*, tooth.

MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix. *Matrix*, womb.

MECHANICAL ORIGIN, ROCKS OF. Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystalline texture, which are of chemical origin.

MEDUSÆ. A genus of marine radiated animals, without shells; so called because their organs of motion spread out like the snaky hair of the fabulous Medusa.

MEGALOSAURUS. A fossil gigantic amphibious animal of the saurian or lizard and crocodile tribe. *Etym.*, *μεγαλη*, *megale*, great, and *σαυρα*, *saura*, lizard.

MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, *μεγα*, *mega*, great, and *θηριον*, *therion*, wild beast.

MELASTOMA. A genus of MELASTOMACEA, an order of exotic plants of the evergreen tree, and shrubby kinds. *Etym.*, *μελας*, *melas*, black, and *στομα*, *stoma*, mouth; because the fruit of one of the species stains the lips.

MESOTYPE. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the trap rocks.

METAMORPHIC ROCKS. For an explanation of this term, see Vol. IV. p. 386.

MICA. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life, but mineralogists apply

the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.

Mica-slate, Mica-schist, Micaceous Schistus. One of the lowest of the stratified rocks, belonging to the hypogene or primary class, which is characterized by being composed of a large proportion of mica united with quartz.

Miocene. See an explanation of this term, Vol. III. p. 392.

Molasse. A provincial name for a soft green sandstone, associated with marl and conglomerates, belonging to the Miocene tertiary period, extensively developed in the lower country of Switzerland. See Vol. IV. p. 140. *Etym.*, French, *molle*, soft.

Mollusca, Molluscous Animals. Animals, such as shell-fish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

Monad. The smallest of visible animalcules, spoken of by Buffon and his followers as constituting the elementary molecules of organic beings.

Monitor. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

Monocotyledonous. A grand division of the vegetable kingdom (including palms, grasses, lilaceæ, &c.), founded on the plant having only one *cotyledon*, or seed lobe. *Etym.*, *μονος*, *monos*, single.

Moschus. A quadruped resembling the chamois or mountain goat, from which the perfume musk is obtained.

Mountain Limestone. A series of limestone strata, of which the geological position is immediately below the coal measures, and with which they also sometimes alternate. See Table I., M, Vol. IV. p. 312.

Moya. A term applied in South America to mud poured out from volcanos during eruptions.

Multilocular. Many-chambered, a term applied to those shells which, like the nautilus, ammonite, and others, are divided into many compartments. *Etym.*, *multus*, many, and *loculus*, a partition.

Muriate of Soda. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

Musaceæ. A family of tropical monocotyledonous plants, including the banana and plantains.

MUSCHELKALK. A limestone which, in geological position, belongs to the red sandstone group. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone. *Etym.*, *muschel*, shell, and *kalkstein*, limestone. See Table I., K, Vol. IV. p. 312.

NAPTHA. A very thin, volatile, inflammable, and fluid mineral substance, of which there are springs in many countries, particularly in volcanic districts.

NENUPHAR. A yellow water-lily.

NEW RED SANDSTONE. A series of sandy, argillaceous, and often calcareous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish grey. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. The European formation so called lies in a geological position immediately above the coal measures. See Table I., K, Vol. IV. p. 313.

NODULE. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

NORMAL GROUPS. Groups of certain rocks taken as a rule or standard. *Etym.*, *norma*, rule or pattern.

NUCLEUS. A solid central piece, around which other matter is collected. The word is Latin for kernel.

NUMMULITES. An extinct genus of the order of molluscous animals called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and λιθος, *lithos*, stone, from its resemblance to a coin.

OBSIDIAN. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced, most probably, by water that was contained in or had access to the melted stone, and converted into steam. There are very often portions in masses of solid obsidian, which are partially converted into pumice.

OGYGIAN DELUGE. A great inundation mentioned in fabulous

history, supposed to have taken place in the reign of Ogyges in Attica, whose death is fixed in Blair's Chronological Tables in the year 1764 before Christ.

Old Red Sandstone. A stratified rock belonging to the Carboniferous Group. See Table I., N. Vol. IV. p. 313.

Olivine. An olive-coloured, semi-transparent, simple mineral, very often occurring in the form of grains and of crystals in basalt and lava.

Oolite, Oolitic. A limestone, so named because it is composed of rounded particles, like the roe or eggs of a fish. The name is also applied to a large group of strata, H, Table I. Vol. IV. p. 310, characterized by peculiar fossils, because limestone of this kind occurs in this group in England, France, &c. *Etym.*, *ωον*, *oon*, egg, and *λιθος*, *lithos*, stone.

Opalized Wood. Wood petrified by siliceous earth, and acquiring a structure similar to the simple mineral called opal.

Ophidious Reptiles. Vertebrated animals, such as snakes and serpents. *Etym.*, *οφις*, *ophis*, a serpent.

Organic Remains. The remains of animals and plants (*organized* bodies) found in a fossil state.

Orthocerata, or Orthoceræ. An extinct genus of the order of molluscous animals, called Cephalopoda, that inhabited a long-chambered conical shell, like a straight horn. *Etym.*, *ορθος*, *orthos*, straight, and *κερας*, *ceras*, horn.

Osseous Breccia. The cemented mass of fragments of bones of extinct animals found in caverns and fissures. *Osseus* is a Latin adjective, signifying bony.

Osteology. That division of anatomy which treats of the bones, from *οστεον*, *osteon*, bone, and *λογος*, *logos*, a discourse.

Outliers. When a portion of a stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier* and the term is adopted in geological language.

Ovate. The shape of an egg. *Etym.*, *ovum*, egg.

Ovipositing. The laying of eggs.

Oxide. The combination of a metal with oxygen; rust is oxide of iron.

Oxygen. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.*, παχυς, *pachus*, thick, and δερμα, *derma*, skin, or hide.

PACHYDERMATOUS. Belonging to pachydermata.

PALÆOTHERIUM, PALEOTHERE. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig, or tapir, but of great size. *Etym.*, παλαιος *palaios*, ancient, and θηριον, *therion*, wild beast.

PALEONTOLOGY. The science which treats of fossil remains, both animal and vegetable. *Etym.*, παλαιος, *pelaios*, ancient, οντα, *onta*, beings, and λογος, *logos*, a discourse.

PELAGIAN, PELAGIC. Belonging to the *deep* sea. *Etym.*, *pelagus*, sea.

PEPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriæ, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym.*, *petra*, rock, and *oleum*, oil.

PHÆNOGAMOUS or PHANEROGAMIC PLANTS. A name given by Linnæus to those plants in which the reproductive organs are apparent. *Etym.*, φανερος, *phaneros*, evident, or φαινω, *phaino*, to show, and γαμος, *gamos*, marriage.

PHLEGRÆAN FIELDS. Campi Phlegræi, or "the Burnt Fields." The country around Naples, so named by the Greeks, from the traces of igneous action every where visible.

PHONOLITE. See Clinkstone.

PHRYGANEA. A genus of four-winged insects, the larvæ of which, called caddis worms, are used by anglers as a bait.

PHYSICS. The department of science which treats of the properties of natural bodies, laws of motion, &c.; sometimes called natural philosophy and mechanical philosophy. *Etym.*, φυσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants — synonymous with botany and botanical. *Etym.*, φυτον, *phyton*, plant, and λογος, *logos*, discourse.

PHYTOPHAGOUS. Plant-eating. *Etym.*, φυτον, *phyton*, plant, and φαγειν, *phagein*, to eat.

Pisolite. A stone possessing a structure like an agglutination of pease. *Etym.*, πισον, *pison*, pea, and λιθος, *lithos*, stone.

Pistia. Vol. III. p. 63. The plant mentioned by Malte-Brun is probably the *Pistia Stratiotes*, a floating plant, related to English duck-weed, but very much larger.

Pit Coal. Ordinary coal; called so because it is obtained by sinking pits in the ground.

Pitch Stone. A rock of a uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance like indurated pitch.

Plastic Clay. One of the beds of the Eocene tertiary period (see Table I. E, Vol. IV. p. 309.), so called because it is used for making pottery. The formation to which this name is applied is a series of beds chiefly sands, with which the clay is associated. *Etym.*, πλασσω, *plasso*, to form or fashion.

Plesiosaurus. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.*, πλησιον, *plesion*, near to, and σαυρα, *saura*, a lizard.

Pliocene. See explanation of this term, Vol. III. p. 390.

Plutonic Rocks. Granite, porphyry, and other igneous rocks, supposed to have consolidated from a melted state at a great depth from the surface. For an explanation of this term, see Vol. IV. p. 344.

Polyparia. Corals. A numerous class of invertebrated animals, belonging to the great division called Radiata.

Porphyry. An unstratified or igneous rock. The term is as old as the time of Pliny, and was applied to a red rock with small, angular, white bodies diffused through it, which are crystallized felspar, brought from Egypt. The term is hence applied to every species of unstratified rock in which detached crystals of felspar or some other mineral are diffused through a base of other mineral composition. *Etym.*, πορφυρα, *porphyra*, purple.

Portland Limestone, Portland Beds. A series of limestone strata, belonging to the upper part of the Oolite Group (see Table I. H, Vol. IV. p. 310.), found chiefly in England, in the Island of Portland on the coast of Dorsetshire. The great supply of the building stone used in London is from these quarries.

Pozzuolana. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called in this country Roman cement. It gets its name from Pozzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

Precipitate. Substances which having been dissolved in a fluid, are separated from it by combining chemically and forming a solid, which falls to the bottom of the fluid. This process is the opposite to that of chemical solution.

Producta. An extinct genus of fossil bivalve shells, occurring only in the older secondary rocks. It is closely allied to the living genus Terebratula.

Pubescence. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

Puddingstone. See "Conglomerate."

Pumice. A light spongy lava, of a white colour, produced by gases, or watery vapour getting access to the particular kind of glassy lava called obsidian, when in a state of fusion—it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

Purbeck Limestone, Purbeck Beds. Limestone strata belonging to the Wealden Group. See Table I. G, Vol. IV. p. 310.

Pyrites (Iron). A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock stratified and unstratified. The shining metallic bodies, so often seen in common roofing slate, are a familiar example of the mineral. The word is Greek, and comes from *πυρ*, *pyr*, fire; because, under particular circumstances, the stone produces spontaneous heat, and even inflammation.

Pyrometer. An instrument for measuring intense degrees of heat.

Quadrumana. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivative of the Latin word for the number four, and *manus*, hand; the four feet of those animals being in some degree usable as hands.

Qua-qua-versal Dip. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.*, *quâ-quâ versum*, on every side.

Quartz. A German provincial term, universally adopted in scientific language, for a simple mineral composed of pure silex, or earth of flints: rock-crystal is an example.

Red Marl. A term often applied to the New Red Sandstone, which is the principal member of the Red Sandstone Group. See Table I. K, Vol. IV. p. 311.

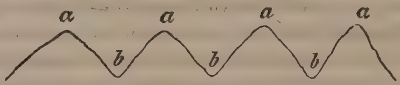
Reticulate. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

Rock Salt. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire, and it is then called *rock*-salt.

Ruminantia. Animals which ruminate or chew the cud, such as the ox, deer, &c. *Etym.*, the Latin verb *rumino*, meaning the same thing.

Saccharoid, Saccharine. When a stone has a texture resembling that of loaf-sugar. *Etym.*, *σακχαρ*, *sacchar*, sugar, and *ειδος*, *eidos*, form.

Salient angle. In a zigzag line, *a a* are the salient angles, *b b* the re-entering angles. *Etym.*, *salire*, to leap or bound forward.



Salt Springs. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.

Sandstone. Any stone which is composed of an agglutination of grains of sand, whether calcareous, siliceous, or of any other mineral nature.

Saurian. Any animal belonging to the lizard tribe. *Etym.*, *σαυρα*, *saura*, a lizard.

Schist is often used as synonymous with slate; but it may be very useful to distinguish between a schistose and a slaty structure. The granitic or primary *schists*, as they are termed, such as gneiss, mica-schist, and others, cannot be split into an inde-

finite number of parallel laminæ, like rocks which have a true slaty cleavage. The uneven schistose layers of mica-schist and gneiss are probably layers of deposition which have assumed a crystalline texture. See "Cleavage." *Etym.*, *schistus*, adj. Latin; that which may be split.

Schistose Rocks. See "Schist."

Scoriæ. Volcanic cinders. The word is Latin for cinders.

Seams. Thin layers which separate two strata of greater magnitude.

Secondary Strata. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them, called *primary*, and from a third series above them called *tertiary*. See Vol. IV. p. 281., and Table I. Vol. IV. p. 308.

Secular Refrigeration. The periodical cooling and consolidation of the globe from a supposed original state of fluidity from heat. *Sæculum*, age or period.

Sedimentary Rocks, are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

Selenite. Crystallized gypsum, or sulphate of lime — a simple mineral.

Septaria. Flattened balls of stone, generally a kind of ironstone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.

Serpentine. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of colour, like the skin of some serpents.

Shale. A provincial term, adopted by geologists, to express an indurated slaty clay. *Etym.*, German *schalen*, to peel, to split.

Shell Marl. A deposit of clay, peat, and other substances mixed with shells, which collects at the bottom of lakes.

Shingle. The loose and completely water-worn gravel on the sea-shore.

Silex. The name of one of the pure earths, being the Latin

word for *flint*, which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.

SILICA. One of the pure earths. *Etym.*, *silex*, flint, because found in that mineral.

SILICATE. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.

SILICEOUS. Of or belonging to the earth of flint. *Etym.*, *silex*, which see. A siliceous rock is one mainly composed of silex.

SILICIFIED. Any substance that is petrified or mineralized by *siliceous* earth.

SILT. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus the mouth of a river is silted up when its entrance into the sea is impeded by such accumulation of loose materials.

SIMPLE MINERAL. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature; for, when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral in the sense we use the term, but it is a chemical compound of sulphur and iron.

SLATE. See "Cleavage" and "Schist."

SOLFATARA. A volcanic vent from which sulphur, sulphureous, watery, and acid vapours and gases are emitted.

SPORULES. The reproductory corpuscula (minute bodies) of cryptogamic plants. *Etym.*, σπορα, *spora*, a seed.

STALACTITE. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, σταλαζω, *stalazo*, to drop.

STALAGMITE. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone: such a crust is called *stalagmite*, from σταλαγμα, *stalagma*, a drop, in opposition to *stalactite*, which see.

Statical Figure. The figure which results from the equilibrium of forces. From στατος, *statos*, stable, or standing still.

Sternum. The breast bone, or the flat bone occupying the front of the chest.

Stilbite. A crystallized simple mineral, usually white, one of the Zeolite family, frequently included in the mass of the trap rocks.

Stratified. Rocks arranged in the form of *strata*, which see.

Stratification. An arrangement of rocks in *strata*, which see.

Strata, Stratum. The term stratum, derived from the Latin verb *struo*, to strew or lay out, means a bed or mass of matter spread out over a certain surface by the action of water, or in some cases by wind. The deposition of successive layers of sand and gravel in the bed of a river, or in a canal, affords a perfect illustration both of the form and origin of stratification. A large portion of the masses constituting the earth's crust are thus stratified, the successive strata of a given rock, preserving a general parallelism to each other; but the planes of stratification not being perfectly parallel throughout a great extent like the planes of *cleavage*, which see.

Strike. The direction or line of bearing of strata, which is always at right angles to their prevailing dip. For a fuller explanation, see Vol. IV. p. 338.

Subapennines. Low hills which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene period.

Syenite. A kind of granite, so called because it was brought from Syene in Egypt. For geological acceptation of the term, see Vol. IV. p. 351.

Synclinal Axis. See "Anticlinal." *Etym.*, συν, *syn*, together, and κλινω, *clino*, to incline.

Talus. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

TARSI. The feet in insects, which are articulated, and formed of five or a less number of joints.

TERTIARY STRATA. A series of sedimentary rocks, with characters which distinguish them from two other great series of strata — the secondary and primary, which lie *beneath* them.

TESTACEA. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

THERMAL. Hot. *Etym.*, *θερμος*, *thermos*, hot.

THERMO-ELECTRICITY. Electricity developed by heat.

THIN OUT. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out, or disappear.

TRACHYTE. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of porphyry. It sometimes contains hornblende and augite; and when these last predominate, the trachyte passes into the varieties of trap called greenstone, basalt, dolorite, &c. The term is derived from *τραχυς*, *trachus*, rough, because the rock has a peculiar rough feel.

TRAP and TRAPPEAN ROCKS. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as basalt, amygdaloid, dolorite, greenstone, and others. The term is derived from *trappa*, a Swedish word for stair, because the rocks of this class sometimes occur in large tabular masses, rising one above another, like steps. For further explanation, see Vol. IV. p. 352.

TRAVERTIN. A concretionary limestone, usually hard and semicrystalline, deposited from the water of springs holding lime in solution. *Etym.* This stone was called by the ancients Lapis Tiburtinus, the stone being formed in great quantity by the river Anio, at Tibur, near Rome. Some suppose travertin to be an abbreviation of trasteverino from transtiburtinus.

TROPHI, of Insects. Organs which form the mouth, consisting of

an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

TUFA, CALCAREOUS. A porous rock deposited by calcareous waters on their exposure to the air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime. The more solid form of the same deposit is called "travertin," into which it passes.

TUFA, VOLCANIC. See "Tuff."

TUFACEOUS. A rock with the texture of tuff or tufa, which see.

TUFF or TUFA, VOLCANIC. An Italian name for a variety of volcanic rock of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose matter ejected from a volcano.

TURBINATED. Shells which have a spiral or screw-form structure. *Etym.*, *turbinatus*, made like a top.

UNCONFORMABLE. See "Conformable."

UNOXIDIZED, UNOXIDATED. Not combined with oxygen.

VEINS, MINERAL. Cracks in rocks filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal, hence their name.

VERTEBRATED ANIMALS. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

VESICLE. A small, circular, inclosed space, like a little bladder. *Etym.*, diminutive of *vesica*, Latin for a bladder.

VITRIFICATION. The conversion of a body into glass by heat.

VOLCANIC BOMBS. Volcanos throw out sometimes detached masses of melted lava, which, as they fall, asssume rounded forms (like bomb-shells), and are often elongated into a pear shape.

VOLCANIC FOCI. The subterranean centres of action in volcanos, where the heat is supposed to be in the highest degree of energy.

Wacke. A rock nearly allied to basalt, of which it may be regarded as a soft and earthy variety.

Zeolite. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ζεω, *zeo*, to boil, and λιθος, *lithos*, stone.

Zoophytes. Corals, sponges, and other aquatic animals allied to them; so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym.*, ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

END OF THE FIRST VOLUME.

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CHAPTER VI.

DESTROYING AND TRANSPORTING EFFECTS OF TIDES AND CURRENTS.

Differences in the rise of the tides — Rennell's Account of the Lagullas and Gulf currents — Velocity of currents — Causes of currents — Action of the sea on the British coast (p. 12.) — Shetland Islands — Large blocks removed — Effects of lightning — Isles reduced to clusters of rocks — Orkney Isles — East coast of Scotland (p. 19.) — East coast of England — Waste of the cliffs of Holderness, Norfolk, and Suffolk — Silting up of estuaries (p. 27.) — Origin of submarine forests — Yarmouth estuary — Suffolk coast — Dunwich (p. 31.) — Essex coast — Estuary of the Thames — Goodwin Sands — Coast of Kent — Formation of Straits of Dover (p. 39.) — South coast of England — Sussex — Hants — Dorset — Portland — Origin of the Chesil Bank (p. 47.) — Cornwall — Coast of Brittany.

Although the movements of great bodies of water, termed tides and currents, are in general due to very distinct causes, their effects cannot be studied separately; for they produce, by their joint action, those

changes which are objects of geological interest. These forces may be viewed in the same manner as we before considered rivers, first, as employed in destroying portions of the solid crust of the earth, and removing them to other places; secondly, as reproductive of new strata.

Tides.—It would be superfluous at the present day to offer any remarks on the cause of the tides. They are not perceptible in lakes, or in most inland seas; in the Mediterranean even, deep and extensive as is that sea, they are scarcely sensible to ordinary observation, their effects being quite subordinate to those of the winds and currents. In some places however, as in the Straits of Messina, there is an ebb and flow to the amount of two feet and upwards; at Naples and at the Euripus, of twelve or thirteen inches; and at Venice, according to Rennell, of five feet.* In the Syrtes, also, of the ancients, two wide shallow gulfs which penetrate very far within the northern coast of Africa, between Carthage and Cyrene, the rise is said to exceed five feet.†

In islands remote from any continent, the ebb and flow of the ocean is very slight, as at St. Helena, for example, where it is rarely above three feet.‡ In any given line of coast, the tides are greatest in narrow channels, bays, and estuaries, and least in the intervening tracts where the land is prominent. Thus, at the entrance of the estuary of the Thames and Medway, the rise of the spring-tides is eighteen feet; but when we follow our eastern coast from thence northward,

* Geography of Herodotus, vol. ii. p. 331.

† Ibid. p. 328.

‡ Romme, Vents et Courans, vol. ii. p. 2. Rev. F. Fallows, Quart. Journ. of Science, March, 1829.

towards Lowestoff and Yarmouth, we find a gradual diminution, until, at the places last mentioned, the highest rise is only seven or eight feet. From this point there begins again to be an increase, so that at Cromer, where the coast again retires towards the west, the rise is sixteen feet; and towards the extremity of the gulf called "the Wash," as at Lynn and in Boston deeps, it is from twenty-two to twenty-four feet, and in some extraordinary cases twenty-six feet. From thence again there is a decrease towards the north, the elevation at the Spurn Point being from nineteen to twenty feet, and at Flamborough Head and the Yorkshire coast from fourteen to sixteen feet.*

At Milford Haven in Pembrokeshire, at the mouth of the Bristol Channel, the tides rise thirty-six feet; and at King-Road near Bristol, forty-two feet. At Chepstow on the Wye, a small river which opens into the estuary of the Severn, they reach fifty feet, and sometimes sixty-nine, and even seventy-two feet.† A current which sets in on the French coast, to the west of Cape La Hague, becomes pent up by Guernsey, Jersey, and other islands, till the rise of the tide is from twenty to forty-five feet, which last height it attains at Jersey, and at St. Malo, a seaport of Brittany.

Currents.—The most extensive and best determined system of currents, is that which has its source in the Indian Ocean, under the influence of the trade winds; and which, after doubling the Cape of Good Hope, inclines to the northward, along the western coast of Africa, then crosses the Atlantic, near the equator, and is lost in the Caribbean Sea, yet seems to be again

* The heights of these tides are given on the authority Captain Hewett, R. N.

† On the authority of Captain Beaufort, R. N.

revived in the current which issues from the gulf of Mexico, by the straits of Bahama, and flows rapidly in a north-easterly direction by the bank of Newfoundland, towards the Azores.

We learn from the posthumous work of Rennell on this subject, that the Lagullas current, so called from the cape and bank of that name, is formed by the junction of two streams, flowing from the Indian Ocean; the one from the channel of Mozambique, down the south-east coast of Africa; the other, from the ocean at large. The collective stream is from ninety to one hundred miles in breadth, and runs at the rate of from two and a half to more than four miles per hour. It is at length turned westward by the Lagullas bank, which rises from a sea of great depth to within one hundred fathoms of the surface. It must, therefore, be inferred, says Rennell, that the current here is more than one hundred fathoms deep, otherwise the main body of it would pass across the bank, instead of being deflected eastward, so as to flow round the Cape of Good Hope. From this cape it flows northward, along the western coast of Africa, taking the name of the South Atlantic current. It then enters the Bight, or Bay of Benin, and is turned westward, partly by the form of the coast there, and partly, perhaps, by the Guinea current, which runs from the north into the same great bay. From the centre of this bay proceeds the Equatorial current, holding a westerly direction across the Atlantic, which it traverses, from the coast of Guinea to that of Brazil, flowing afterwards by the shores of Guiana to the West Indies. The breadth of this current varies from 160 to 450 geographical miles, and its velocity is from twenty-five to seventy-nine

miles per day, the mean rate being about thirty miles. The length of its whole course is about 4000 miles. As it skirts the coast of Guinea, it is increased by the influx of the waters of the Amazon and Orinoco, and by their junction acquires accelerated velocity. After passing the island of Trinidad, it expands, and is almost lost in the Caribbean Sea; but there appears to be a general movement of that sea towards the Mexican gulf, which discharges the most powerful of all currents through the straits of Florida, where the waters run in the northern part with a velocity of five miles an hour, having a breadth of from thirty-five to fifty miles.

The temperature of the gulf of Mexico is 86°, in summer, or 6° higher than that of the ocean, in the same parallel (25° N. lat.), and a large proportion of this warmth is retained, even where the stream reaches the 43° N. lat. After issuing from the straits of Florida, the current runs in a northerly direction to Cape Hatteras, in North Carolina, about 35° N. lat., where it is more than seventy miles broad, and still moves at the rate of seventy-five miles per day. In about the 40° N. lat., it is turned more towards the Atlantic by the extensive banks of Nantucket, and St. George, which are from 200 to 300 feet beneath the surface of the sea; a clear proof that the current exceeds that depth. On arriving near the Azores, the stream widens, and overflows, as it were, forming a large expanse of warm water in the centre of the North Atlantic, over a space of 200 or 300 miles from north to south, and having a temperature of from 8° to 10° Fahr. above the surrounding ocean. The whole area, covered by the gulf water, is estimated by Rennell at 2000 miles in length, and, at a mean, 350 miles in breadth; an area

more extensive than that of the Mediterranean. The warm water has been sometimes known to reach the Bay of Biscay, still retaining five degrees of temperature above that of the adjoining ocean, and a branch of the gulf current occasionally drifts fruits, plants, and wood, the produce of America, and the West Indies, to the shores of Ireland, and the Hebrides.

The above statements prepare us to understand the description, given by Rennell, of the principal currents, which, he says, are oceanic rivers, from fifty to 250 miles in breadth, having a rapidity exceeding that of the largest navigable rivers of the continents, and so deep as to be sometimes obstructed, and occasionally turned aside, by banks which do not rise within forty or fifty fathoms of the surface of the sea.*

Greatest Velocity of Currents.—The ordinary velocity of the principal currents of the ocean is from one to three miles per hour; but when the boundary lands converge, large bodies of water are driven gradually into a narrower space, and then wanting lateral room are compelled to raise their level. Whenever this occurs, their velocity is much increased. The current which runs through the Race of Alderney, between the island of that name and the main land, has a velocity of above eight *English* miles an hour. Captain Hewett found that, in the Pentland Firth the stream, in ordinary spring tides, runs ten miles and a half an hour, and about thirteen miles during violent storms. The greatest velocity of the tidal current through the "Shoots," or New Passage, in the Bristol Channel, is fourteen English miles an hour; and Captain King observed, in his recent survey of the Straits of Magellan, that the tide ran at the same rate through the "First Narrows."

* Rennell on Currents, p. 58.

Causes of Currents. — That movements of no inconsiderable magnitude should be impressed on an expansive ocean, by winds blowing for many months in one direction, may easily be conceived, when we observe the effects produced in our own seas by the temporary action of the same cause. It is well known that a strong south-west or north-west wind invariably raises the tides to an unusual height along the east coast of England and in the Channel; and that a north-west wind of any continuance causes the Baltic to rise two feet and upwards above its ordinary level. Smeaton ascertained by experiment that, in a canal four miles in length, the water was kept up four inches higher at one end than at the other, merely by the action of the wind along the canal; and Rennell informs us that a large piece of water, ten miles broad, and generally only three feet deep, has, by a strong wind, had its waters driven to one side, and sustained so as to become six feet deep, while the windward side was laid dry.*

As water, therefore, he observes, when pent up so that it cannot escape, acquires a higher level, so, in a place *where it can escape*, the same operation produces a current; and this current will extend to a greater or less distance, according to the force by which it is produced.

Currents flowing alternately in opposite directions are also occasioned by the rise and fall of the tides. The effect of this cause is, as before observed, most striking in estuaries and channels between islands.

A third cause of oceanic currents is evaporation by solar heat, of which the great current setting through the Straits of Gibraltar into the Mediter-

* Rennell on the Channel-current.

ranean is a remarkable example, and will be fully considered in the next chapter. A stream of colder water also flows from the Black Sea into the Mediterranean. It must happen in many other parts of the world that large quantities of water raised from one tract of the ocean by solar heat, are carried to some other where the vapour is condensed and falls in the shape of rain, and this in flowing back again to restore equilibrium, will cause sensible currents.

But there is another way in which heat and cold must occasion currents in the ocean. It is now ascertained that there is no maximum of density in salt water — no point, as in fresh water, at which an increase of cold causes the fluid to begin again to expand. Whenever, therefore, the temperature of the surface is lowered, condensation takes place, and the superficial water, having its specific gravity increased, falls to the bottom, upon which lighter water rises immediately and occupies its place. When this circulation of ascending and descending currents has gone on for a certain time in high latitudes, the inferior parts of the sea are made to consist of colder or heavier fluid than the corresponding depths of the ocean between the tropics. If there be a free communication, if no chain of submarine mountains divide the polar from the equatorial basins, a horizontal movement will arise by the flowing of colder water from the poles to the equator, and there will then be a reflux of warmer superficial water from the equator to the poles. A well-known experiment has been adduced to elucidate this mode of action in explanation of the "trade winds."* If a long

* See Capt. B. Hall's clear Explanation of the Theory of the Trade Winds, Fragments of Voyages, second series, vol. i. and his letter in the Appendix to Daniell's Meteorology.

trough, divided in the middle by a sluice or partition, have one end filled with water and the other with quicksilver, both fluids will remain quiet so long as they are divided; but when the sluice is drawn up, the heavier fluid will rush along the bottom of the trough, while the lighter, being displaced, will rise; and, flowing in an opposite direction, spread itself at the top. Hence it appears, that the expansion and contraction of sea-water by heat and cold have a tendency to set under-currents in motion from the poles to the equator, and to cause counter-currents at the surface which are impelled in a direction contrary to that of the prevailing trade winds. The circumstances being very complicated, we cannot expect to trace separately the movements due to each cause, but must be prepared for many anomalies, especially as the configuration of the bed of the ocean must often modify and interfere with the course of the inferior currents, as much as the position and form of continents and islands are found to alter the direction of those on the surface.

Each of the four causes above mentioned, the wind, the tides, evaporation, and expansion of water by heat, may be conceived to operate independently of the others, and although the influence of all the rest were annihilated. But there is another cause, the rotation of the earth on its axis, which can only come into play when the waters have already been set in motion by some one or all of the forces above described, and only when the direction of the current so raised happens to be from south to north, or from north to south.*

* In an interesting essay in the United Service Journal (Dec. 1833), an attempt is made to introduce the earth's rotation as a

The principle on which this cause operates is probably familiar to the reader, as it has long been recognized in the case of the trade winds. Without enlarging, therefore, on the theory, it will be sufficient to offer an example of the mode of action alluded to. When a current flows from the Cape of Good Hope towards the Gulf of Guinea, it consists of a mass of water, which, on doubling the Cape, in lat. 35°, has a rotatory velocity of about 800 miles an hour; but when it reaches the line, it arrives at a parallel where the surface of the earth is whirled round at the rate of 1000 miles an hour, or about 200 miles faster.* If this great mass of water was transferred suddenly from the higher to the lower latitude, the deficiency of its rotatory motion, relatively to the land and water with which it would come into juxtaposition would be such as to cause an apparent motion of the most rapid kind (of no less than 200 miles an hour) from east to west.

In the case of such a sudden transfer the eastern coast of America might be carried round so as to strike against a large body of water with tremendous violence, and a considerable part of the continent might be submerged. This disturbance does not occur, because the water of the stream, as it advances gra-

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primary cause of currents. But the author appears to misconceive the mode in which alone this rotation could produce any effect, and reasons as if it would in all latitudes cause currents from east to west. He also seems never to have heard of Mr. Lloyd's levellings across the Isthmus of Panama, by which the waters of the Gulf of Mexico are proved (if there be any difference) to be lower than the mean level of the Pacific, and he also assumes that the quantity of rain is greatly in excess in *high* instead of *low* latitudes.

* See a table in Capt. Hall's work before cited.

dually into new zones of the sea which are moving more rapidly, acquires by friction an accelerated velocity. Yet as this motion is not imparted instantaneously, the fluid is unable to keep up with the full speed of the new surface over which it is successively brought. Hence, to borrow the language of Herschel, when he speaks of the trade winds, "it lags or hangs back, in a direction opposite to the earth's rotation, that is, from east to west*," and thus a current which would have run simply towards the north but for the rotation, may acquire a relative direction towards the west, or become a south-easterly current.

We may next consider a case where the circumstances are the converse of the above. The Gulf stream flowing from about lat. 20°, is at first impressed with a velocity of rotation of about 940 miles an hour, and runs to the lat. 40°, where the earth revolves only at the rate of 766 miles, or 174 miles slower. In this case a relative motion of an opposite kind may result; and the current may retain an excess of rotatory velocity, tending continually to deflect it eastward.

Thus it will be seen that currents depend like the tides on no temporary or accidental circumstances, but on the laws which preside over the motions of the heavenly bodies. But although the sum of their influence in altering the surface of the earth may be very constant throughout successive epochs, yet the points where these operations are displayed in fullest energy shift perpetually. The height to which the tides rise, and the violence and velocity of currents, depend in a great measure on the actual configuration of the land, the contour of a long line of continental or

* Treatise on Astronomy, chap. 3.

insular coast, the depth and breadth of channels, the peculiar form of the bottom of seas — in a word, on a combination of circumstances which are made to vary continually by many igneous and aqueous causes, and, among the rest, by the tides and currents themselves. Although these agents, therefore, of decay and reproduction are local in reference to periods of short duration, such as those which history embraces, they are nevertheless universal, if we extend our views to a sufficient lapse of ages.

Action of the Sea on the British Coasts. — If we follow the eastern and southern shores of the British islands, from our Ultima Thule in Shetland to the Land's End in Cornwall, we shall find evidence of a series of changes since the historical era, very illustrative of the kind and degree of force exerted by tides and currents, co-operating with the waves of the sea. In this survey we shall have an opportunity of tracing their joint power on islands, promontories, bays, and estuaries; on bold, lofty cliffs, as well as on low shores; and on every description of rock and soil, from granite to blown sand.

Shetland Islands. — The northernmost group of the British islands, the Shetland, are composed of a great variety of rocks, including granite, gneiss, mica-slate, serpentine, greenstone, and many others, with some secondary rocks, chiefly sandstone and conglomerate. These islands are exposed continually to the uncontrolled violence of the Atlantic, for no land intervenes between their western shores and America. The prevalence, therefore, of strong westerly gales causes the waves to be sometimes driven with irresistible force upon the coast, while there is also a current setting from the north. The spray of the sea aids the decom-

position of the rocks, and prepares them to be breached by the mechanical force of the waves. Steep cliffs are hollowed out into deep caves and lofty arches; and almost every promontory ends in a cluster of rocks, imitating the forms of columns, pinnacles, and obelisks.

Drifting of large Masses of Rock. — Modern observations show that the reduction of continuous tracts to such insular masses is a process in which Nature is still actively engaged. "The Isle of Stenness," says Dr. Hibbert, "presents a scene of unequalled desolation. In stormy winters, huge blocks of stones are overturned or are removed from their native beds, and hurried up a slight acclivity to a distance almost incredible. In the winter of 1802, a tabular-shaped mass, eight feet two inches by seven feet, and five feet one inch thick, was dislodged from its bed, and removed to a distance of from eighty to ninety feet. I measured the recent bed from which a block had been carried away the preceding winter (A. D. 1818), and found it to be seventeen feet and a half by seven feet, and the depth two feet eight inches. The removed mass had been borne to a distance of thirty feet, when it was shivered into thirteen or more lesser fragments, some of which were carried still farther, from 30 to 120 feet. A block, nine feet two inches by six feet and a half, and four feet thick, was hurried up the acclivity to a distance of 150 feet." *

At Northmavine, also, angular blocks of stone have been removed in a similar manner to considerable distances by the waves of the sea, some of which are represented in the annexed figure.†

* Descrip. of Shetland Islands, p. 527. Edin. 1822.

† For this and the three following representations of rocks in the Shetland Isles, I am indebted to Dr. Hibbert's work before cited, which is rich in antiquarian and geological research.

Fig. 11.

Stony fragments drifted by the sea. Northmavine, Shetland.

Effects of Lightning. — In addition to numerous examples of masses detached and driven by the waves, tides, and currents from their place, some remarkable effects of lightning are recorded in these isles. At Funzie, in Fetlar, about the middle of the last century, a rock of mica-schist, 105 feet long, ten feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large, and several smaller, fragments. One of these, twenty-six feet long, ten feet broad, and four feet thick, was simply turned over. The second, which was twenty-eight feet long, seventeen broad, and five feet in thickness, was hurled across a high point to the distance of fifty yards. Another broken mass, about forty feet long, was thrown still farther, but in the same direction, quite into the sea. There were also many smaller fragments scattered up and down.*

When we thus see electricity co-operating with the

* Dr. Hibbert, from MSS. of Rev. George Low, of Fetlar.

violent movements of the ocean in heaping up piles of shattered rocks on dry land, and beneath the waters, we cannot but admit that a region which shall be the theatre, for myriads of ages, of the action of such disturbing causes, might present, at some future period, if upraised far above the bosom of the deep, a scene of havoc and ruin that may compare with any now found by the geologist on the surface of our continents.

In some of the Shetland Isles, as on the west of Meikle Roe, dikes, or veins of soft granite, have mouldered away; while the matrix in which they were inclosed, being of the same substance, but of a firmer texture, has remained unaltered. Thus, long narrow ravines, sometimes twenty-feet wide, are laid open, and often give access to the waves. After describing some huge cavernous apertures into which the sea flows for 250 feet in Roeness, Dr. Hibbert enumerates other ravages of the ocean. "A mass of rock, the average dimensions of which may perhaps be rated at twelve or thirteen feet square, and four and a half or five in thickness, was first moved from its bed, about fifty years ago, to a distance of thirty feet, and has since been twice turned over."

Passage forced by the sea through porphyritic rocks.—"But the most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean; — the Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery — the waves having, in their repeated assaults, forced themselves an entrance. This breach, named the Grind of the Navir (Fig. 12.), is widened every winter by the overwhelming surge that, finding a passage through it,

Fig. 12.

Grind of the Navir — Passage forced by the sea through rocks of hard porphyry.

separates large stones from its sides, and forces them to a distance of no less than 180 feet. In two or three spots, the fragments which have been detached are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry." *

It is evident, from this example, that although the greater indestructibility of some rocks may enable them to withstand, for a longer time, the action of the elements, yet they cannot permanently resist. There are localities in Shetland, in which rocks of almost every variety of mineral composition are suffering disintegration; thus the sea makes great inroads on the clay slate of Fitfel Head, on the serpentine of the

* Hibbert, p. 528.

Vord Hill in Fetlar, and on the mica-schist of the Bay of Triesta, on the east coast of the same island, which decomposes into angular blocks. The quartz rock on the east of Walls, and the gneiss and mica-schist of Garthness, suffer the same fate.

Destruction of Islands. — Such devastation cannot be incessantly committed for thousands of years without dividing islands, until they become at last mere clusters of rocks, the last shreds of masses once continuous. To this state many appear to have been reduced, and innumerable fantastic forms are assumed by rocks adjoining these islands, to which the name of Drongs is applied, as it is to those of similar shape in Feroe.

The granitic rocks (Fig. 13.) between Papa Stour and Hillswick Ness afford an example. A still more singular cluster of rocks is seen to the south of Hillswick Ness (Fig. 14.), which presents a variety of forms as viewed from different points, and has often been

Fig. 13.

Granitic rocks named the Drongs, between Papa Stour and Hillswick Ness.

likened to a small fleet of vessels with spread sails.* We may imagine that in the course of time Hillswick

Fig. 14.

Granitic rocks to the south of Hillswick Ness, Shetland.

Ness itself may present a similar wreck, from the unequal decomposition of the rocks whereof it is composed, consisting of gneiss and mica-schist, traversed in all directions by veins of felspar porphyry.

Midway between the groups of Shetland and Orkney is Fair Island, said to be composed of sandstone with high perpendicular cliffs. The current runs with such velocity, that during a calm, and when there is no swell, the rocks on its shores are white with the foam of the sea driven against them. The Orkneys, if carefully examined, would probably illustrate our present topic as much as the Shetland group. The north-east promontory of Sanda, one of these islands, has been cut off in modern times by the sea, so that it became what is now called Start Island, where a light-

* Hibbert, p. 519.

house was erected in 1807, since which time the new strait has grown broader.

East coast of Scotland.—To pass over to the main land of Scotland, we find that, in Inverness-shire, there have been inroads of the sea at Fort George, and others in Murrayshire, which have swept away the old town of Findhorn. On the coast of Kincardineshire, an illustration was afforded, at the close of the last century, of the effect of promontories in protecting a line of low-shore. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach, protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent, that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated 150 yards inland, where it has maintained its ground ever since, the new village having been built farther inland on the new shore. In the Bay of Montrose, we find the North Esk and the South Esk rivers pouring annually into the sea large quantities of sand and pebbles, yet they have formed no deltas; for the tides scour out the channels; and the current, setting across their mouths, sweeps away all the materials. Considerable beds of shingle, brought down by the North Esk, are seen along the beach.

Proceeding southwards, we find that at Arbroath, in Forfarshire, which stands on a rock of red sandstone, gardens and houses have been carried away within the last thirty years by encroachments of the sea. It has become necessary to remove the lighthouses at the mouth of the estuary of the Tay, in the same county, at Button Ness, which were built on a tract of blown sand, the sea having encroached for three quarters of a mile.

Force of Waves and Currents in Estuaries.—The combined power which waves and currents can exert in estuaries to considerable depths, was remarkably exhibited during the building of the Bell Rock Lighthouse, off the mouth of the Tay. The Bell Rock is a sunken reef, consisting of red sandstone, being from twelve to sixteen feet under the surface at high water, and about twelve miles from the mainland. At the distance of 100 yards, there is a depth, in all directions, of two or three fathoms at low water. In 1807, during the erection of the lighthouse, six large blocks of granite, which had been landed on the reef, were removed by the force of the sea, and thrown over a rising ledge to the distance of twelve or fifteen paces; and an anchor, weighing about 22 cwt., was thrown up upon the rock.* Mr. Stevenson informs us, moreover, that drift stones, measuring upwards of thirty cubic feet, or more than two tons weight, have, during storms, been often thrown upon the rock from the deep water.†

Submarine forests.— Among the proofs that the sea has encroached both on the estuaries of the Tay and Forth, may be mentioned the submarine forests which have been traced for several miles by Dr. Fleming, along the margins of those estuaries on the north and south shores of the county of Fife.‡ The alluvial tracts, however, on which such forests grow, generally occupy spaces which may be said to be in dispute between the river and the sea, and to be alternately lost and won. *Estuaries* (a term which we confine to inlets entered both by rivers and tides of the sea)

* Account of the Erection of the Bell Rock Lighthouse, p. 163.

† Ed. Phil. Journ., vol. iii. p. 54. 1820.

‡ Quarterly Journal of Science, &c., No. XIII. New Series, March, 1830.

have a tendency to become silted up in parts; but the same tracts, after remaining dry, perhaps, for thousands of years, are again liable to be overflowed, for they are always low, and, if inhabited, must generally be secured by artificial embankments. Meanwhile the sea devours, as it advances, the high as well as the low parts of the coast, breaking down, one after another, the rocky bulwarks which protect the mouths of estuaries. The changes of territory, therefore, within the general line of coast are all of a subordinate nature, in no way tending to arrest the march of the great ocean, nor to avert the destiny eventually awaiting the whole region: they are like the petty wars and conquests of the independent states and republics of Greece, while the power of Macedon was steadily pressing on, and preparing to swallow up the whole.

On the coast of Fife, at St. Andrew's, a tract of land which intervened between the castle of Cardinal Beaton and the sea, has been entirely swept away, as were the last remains of the Priory of Crail, in the same county, in 1803. On both sides of the Frith of Forth, land has been consumed; at North Berwick in particular, and at Newhaven, where an arsenal and dock, built in the reign of James IV., in the fifteenth century, has been overflowed.

East coast of England.—If we now proceed to the English coast, we find records of numerous lands having been destroyed in Northumberland, as those near Bamborough and Holy Island, and at Tynemouth castle, which now overhangs the sea, although formerly separated from it by a strip of land. At Hartlepool, and several other parts of the coast of Durham com-

posed of magnesian limestone, the sea has made considerable inroads.

Coast of Yorkshire. — Almost the whole coast of Yorkshire, from the mouth of the Tees to that of the Humber, is in a state of gradual dilapidation. That part of the cliffs which consists of lias, the oolite series, and chalk, decays slowly. They present abrupt and naked precipices, often 300 feet in height; and it is only at a few points that the grassy covering of the sloping talus marks a temporary relaxation of the erosive action of the sea. The chalk cliffs are washed into caves in the projecting headland of Flamborough, where they are decomposed by the salt vapours, and slowly crumble away. But the waste is most rapid between that promontory and Spurn Point, or the coast of Holderness, as it is called, a tract consisting of beds of clay, gravel, sand, and chalk rubble. The irregular intermixture of the argillaceous beds causes many springs to be thrown out, and this facilitates the undermining process, the waves beating against them, and a strong current setting chiefly from the north. The wasteful action is very conspicuous at Dimlington Height, the loftiest point in Holderness, where the beacon stands on a cliff 146 feet above high water, the whole being composed of clay, with pebbles scattered through it.*

In the old maps of Yorkshire, we find spots, now sand-banks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde. "Of Hyde," says Pennant, "only the tradition is left; and near the village of Hornsea, a street

* Phillips's Geology of Yorkshire, p. 61.

called Hornsea Beck has long since been swallowed."* Owthorne and its church have also been in great part destroyed, and the village of Kilnsea; but these places are now removed farther inland. The rate of encroachment at Owthorne, at present is about *four yards a year.*† Not unreasonable fears are entertained that at some future time the Spurn Point will become an island, and that the ocean, entering into the estuary of the Humber, will cause great devastation.‡ Pennant, after speaking of the silting up of some ancient ports in that estuary, observes, "But, in return, the sea has made most ample reprisals; the site, and even the very names of several places, once towns of note upon the Humber, are now only recorded in history; and Ravensper was at one time a rival to Hull (Madox, Ant. Exch. i., 422.), and a port so very considerable in 1332, that Edward Baliol and the confederated English Barons sailed from hence to invade Scotland; and Henry IV., in 1399, made choice of this port to land at, to effect the deposal of Richard II.; yet the whole of this has long since been devoured by the merciless ocean: extensive sands, dry at low water, are to be seen in their stead." §

Pennant describes Spurn Head as a promontory in the form of a sickle, and says the land, for some miles to the north, was "perpetually preyed on by the fury of the German Sea, which devours whole acres at a time, and exposes on the shores considerable quantities of beautiful amber." ||

* Arctic Zoology, vol. i. p. 10. Introduction.

† For this information I am indebted to Mr. Phillips, of York.

‡ Phillips's Geology of Yorkshire, p. 60.

§ Arct. Zool. vol. i. p. 13. Introduction.

|| Ibid.

According to Bergmann, a strip of land, with several villages, was carried away near the mouth of the Humber in 1475.

Lincolnshire. — The maritime district of Lincolnshire consists chiefly of lands that lie below the level of the sea, being protected by embankments. Great parts of this fenny tract were, at some unknown period, a woody country, but were afterwards inundated, and are now again recovered from the sea. Some of the fens were embanked and drained by the Romans; but after their departure the sea returned, and large tracts were covered with beds of silt containing marine shells, now again converted into productive lands. Many dreadful catastrophes are recorded by incursions of the sea, whereby several parishes have been at different times overwhelmed.

Norfolk. — We come next to the cliffs of Norfolk and Suffolk, where the decay is in general incessant and rapid. At Hunstanton, on the north, the undermining of the lower arenaceous beds at the foot of the cliff causes masses of red and white chalk to be precipitated from above. Between Hunstanton and Weybourne, low hills, or dunes, of blown sand, are formed along the shore, from fifty to sixty feet high. They are composed of dry sand, bound in a compact mass by the long creeping roots of the plant called Marram (Arundo arenaria). Such is the present set of the tides, that the harbours of Clay, Wells, and other places, are securely defended by these barriers; affording a clear proof that it is not the strength of the material at particular points that determines whether the sea shall be progressive or stationary, but the general contour of the coast.

The waves constantly undermine the low chalk

cliffs, covered with sand and clay, between Weybourne and Sherringham, a certain portion of them being annually removed. At the latter town I ascertained, in 1829, some facts which throw light on the rate at which the sea gains upon the land. It was computed, when the present inn was built, in 1805, that it would require seventy years for the sea to reach the spot: the mean loss of land being calculated, from previous observations, to be somewhat less than one yard annually. The distance between the house and the sea was fifty yards; but no allowance was made for the slope of the ground being *from* the sea, in consequence of which, the waste was naturally accelerated every year, as the cliff grew lower, there being at each succeeding period less matter to remove when portions of equal area fell down. Between the years 1824 and 1829, no less than seventeen yards were swept away, and only a small garden was then left between the building and the sea. There is now a depth of twenty feet (sufficient to float a frigate) at one point in the harbour of that port, where, only forty-eight years ago, there stood a cliff fifty feet high, with houses upon it! If once in half a century an equal amount of change were produced suddenly by the momentary shock of an earthquake, history would be filled with records of such wonderful revolutions of the earth's surface; but, if the conversion of high land into deep sea be gradual, it excites only local attention. The flag-staff of the Preventive Service station, on the south side of this harbour, has, within the last fifteen years, been thrice removed inland, in consequence of the advance of the sea.

Farther to the south we find cliffs, composed, like those of Holderness before mentioned, of alternating

strata of blue clay, gravel, loam, and fine sand. Although they sometimes exceed 200 feet in height, the havoc made on the coast is most formidable. The whole site of ancient Cromer now forms part of the German Ocean, the inhabitants having gradually retreated inland to their present situation, from whence the sea still threatens to dislodge them. In the winter of 1825, a fallen mass was precipitated from near the lighthouse, which covered twelve acres, extending far into the sea, the cliffs being 250 feet in height.* The undermining by springs has sometimes caused large portions of the upper part of the cliffs, with houses still standing upon them, to give way, so that it is impossible, by erecting breakwaters at the base of the cliffs, permanently to ward off the danger.

On the same coast, the ancient villages of Shipden, Wimpwell, and Eccles, have disappeared; several manors and large portions of neighbouring parishes having, piece after piece, been swallowed up; nor has there been any intermission, from time immemorial in the ravages of the sea along a line of coast twenty miles in length, in which these places stood.† Hills of blown sand, between Eccles and Winterton, have barred up and excluded the tide for many hundred years from the mouths of several small estuaries; but there are records of nine breaches from 20 to 120 yards wide, having been made through these, by which immense damage was done to the low grounds in the interior. A few miles south of Happisburgh, also, are hills of blown sand, which extend to Yarmouth; and these are supposed to protect the coast, but in fact their formation proves that a temporary respite of the

* Taylor's Geology of East Norfolk, p. 32. † Ibid.

incursions of the sea on this part is permitted by the present set of the tides and currents. Were it otherwise, the land, as we have seen, would give way, though made of solid rock.

Silting up of Estuaries. — At Yarmouth, the sea has not advanced upon the sands in the slightest degree since the reign of Elizabeth. In the time of the Saxons, a great estuary extended as far as Norwich, which city is represented, even in the thirteenth and fourteenth centuries, as "situated on the banks of an arm of the sea." The sands whereon Yarmouth is built first became firm and habitable ground about the year 1008, from which time a line of dunes has gradually increased in height and breadth, stretching across the whole entrance of the ancient estuary, and obstructing the ingress of the tides so completely, that they are only admitted by the narrow passage which the river keeps open, and which has gradually shifted several miles to the south. The ordinary tides at the river's mouth rise, at present, only to the height of three or four feet, the spring tides to about eight or nine.

By the exclusion of the sea, thousands of acres in the interior have become cultivated lands; and, exclusive of smaller pools, upwards of sixty fresh-water lakes have been formed, varying in depth from fifteen to thirty feet, and in extent from one acre to twelve hundred*. The Yare, and other rivers, frequently communicate with these sheets of water; and thus they are liable to be filled up gradually with lacustrine and fluviatile deposits, and to be converted into land covered with forests. When the sea at length returns (for as the whole coast gives way, this must inevitably happen sooner or later), these tracts will be again sub-

* Taylor's Geology of East Norfolk, p. 10.

merged, and submarine forests may then be found, as along the margins of many estuaries.*

Yarmouth does not project beyond the general line of coast which has been rounded off by the predominating current from the north-west. It must not be imagined, therefore, that the acquisition of new land fit for cultivation in Norfolk and Suffolk indicates any permanent growth of the eastern limits of our island, to compensate its reiterated losses. No *delta* can form on such a shore.

That great banks should be thrown across the estuary of the Yare, or any other estuary on our eastern coast, where there is not a large body of river-water to maintain an open channel, is perfectly intelligible, when we bear in mind that the marine current, sweeping along the coast, is charged with the materials of wasting cliffs, and ready to form a bar anywhere, the instant its course is interrupted or checked by any opposing stream. The mouth of the Yare has been, within the last five centuries, diverted about four miles to the south; so it is evident that at some remote period the river Alde, entered the sea at Aldborough, until its ancient outlet was barred up and at length transferred to a point no less than ten miles distant to the south-west. In this case ridges of sand and shingle like those of Lowestoff Ness, which will be described by-and-by, have been thrown up between the river and the sea; and an ancient sea-cliff is to be seen, now inland.

It may be asked why the rivers on our east coast are always deflected southwards, although the tidal current flows alternately from the south and north? The cause is to be found in the superior force of what

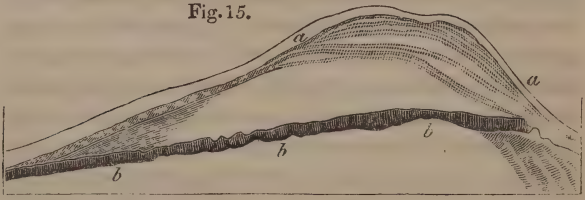
* For remarks on the origin of Submarine Forests, see Book III. chap. 16.

is commonly called "the flood tide from the north," a tidal wave derived from the Atlantic, a small part of which passes eastward up the English Channel, and through the Straits of Dover and then northwards, while the principal body of water, moving much more rapidly in a more open sea, first passes the Orkneys, and then turning flows down between Norway and Scotland, and sweeps with great velocity along our eastern coast. It is well known that the highest tides on this coast are occasioned by a powerful north-west wind which raises the eastern part of the Atlantic, and causes it to pour a greater volume of water into the German ocean. This circumstance of a violent *off-shore* wind being attended with a rise of the waters, instead of a general retreat of the sea, naturally excites the wonder of the inhabitants of our coast. In many districts they look with confidence for a rich harvest of that valuable manure, the sea-weed, when the north-westerly gales prevail, and are rarely disappointed. The phenomenon is so well calculated to awaken curiosity, that I have heard the cause discussed by peasants aud fishermen; and more than once they have hazarded a theory of their own to account for it. The most ingenious idea which I heard suggested was this; a vast body of surface water, say they, is repelled by the wind from the shore, which afterwards returns, in order to restore the level of the sea; by this means a strong under-current is produced, which tears up the weed from the bed of the sea, and casts it ashore. The true explanation, however, of the phenomenon is doubtless that above mentioned.

Coast of Suffolk.—The cliffs of Suffolk, to which we next proceed, are somewhat less elevated than those of Norfolk, but composed of similar alternations of clay,

sand, gravel. From Gorleston in Suffolk, to within a a few miles north of Lowestoff, the cliffs are slowly undermined. Near the last-mentioned town, there is an inland cliff about sixty feet high, the sloping talus of which is covered with turf and heath. Between the cliff and the sea is a low, flat tract of sand, called the Ness, nearly three miles long, and for the most part out of reach of the highest tides. The point of the Ness projects from the base of the original cliff to the distance of 660 yards. This accession of land, says Mr. Taylor, has been effected at distinct and distant intervals, by the influence of currents running between the land and a shoal about a mile off Lowestoff, called the Holm Sand. The lines of growth in the Ness are indicated by a series of concentric ridges or embankments inclosing limited areas, and several of these

Fig. 15.



*Map of Lowestoff Ness, Suffolk.**

a, a. The dotted lines express a series of ridges of sand and shingle, forming the extremity of the triangular space called the Ness.

b, b, b. The dark line represents the inland cliff on which the town of Lowestoff stands, between which and the sea is the Ness.

* From Mr. R. C. Taylor's Mem., see below.

ridges have been formed within the observation of persons now living. A rampart of heavy materials is first thrown up to an unusual altitude by some extraordinary tide, attended with a violent gale. Subsequent tides extend the base of this high bank of shingle, and the interstices are then filled with sand blown from the beach. The Arundo and other marine plants by degrees obtain a footing; and creeping along the ridge, give solidity to the mass, and form in some cases a matted covering of turf. Meanwhile another mound is forming externally, which by the like process rises and gives protection to the first. If the sea forces its way through one of the external and incomplete mounds, the breach is soon repaired. After a while the marine plants within the areas inclosed by these embankments are succeeded by a better species of herbage, affording good pasturage, and the sands become sufficiently firm to support buildings.*

Destruction of Dunwich by the Sea.—The sea undermines the high cliffs near Corton, a few miles north of Lowestoff, as also two miles south of the same town, at Pakefield, a village which has been in part swept away during the present century. From thence to Dunwich the destruction is constant. At the distance of 250 yards from the wasting cliff at Pakefield, where we must suppose land to have existed at no remote period, the sea is sixteen feet deep at low water, and in the roadstead beyond, twenty-four feet. Of the gradual destruction of Dunwich, once the most considerable seaport on this coast, we have many authentic records. Gardner in his history of that borough, pub-

* The formation of the Ness is well described by Mr. R. C. Taylor, Phil. Mag. Oct. 1827. p. 297.

lished in 1754, shows, by reference to documents beginning with Doomsday Book, that the cliffs at Dunwich, Southwold, Eastern, and Pakefield, have been always subject to wear away. At Dunwich, in particular, two tracts of land which had been taxed in the eleventh century, in the time of King Edward the Confessor, are mentioned, in the Conqueror's survey, made but a few years afterwards, as having been devoured by the sea. The losses, at a subsequent period, of a monastery, — at another of several churches,— afterwards of the old port, — then of four hundred houses at once,— of the church of St. Leonard, the high road, town-hall, gaol, and many other buildings, are mentioned, with the dates when they perished. It is stated that, in the sixteenth century, not one quarter of the town was left standing; yet the inhabitants retreating inland, the name was preserved, as has been the case with many other ports, when their ancient site has been blotted out. There is, however, a church, of considerable antiquity, still standing, the last of twelve mentioned in some records. In 1740, the laying open of the churchyard of St. Nicholas and St. Francis, in the sea-cliffs, is well described by Gardner, with the coffins and skeletons exposed to view — some lying on the beach, and rocked —

"In cradle of the rude imperious surge."

Of these cemeteries no remains can now be seen. Ray also says, "that ancient writings make mention of a wood a mile and a half to the east of Dunwich, the site of which must at present be so far within the sea."* This city, once so flourishing and populous, is

* Consequences of the Deluge, Phys. Theol. Discourses.

now a small village, with about twenty houses, and one hundred inhabitants.

There is an old tradition, " that the tailors sat in their shops at Dunwich, and saw the ships in Yarmouth Bay :" but when we consider how far the coast at Lowestoff Ness projects between these places, we cannot give credit to the tale, which, nevertheless, proves how much the inroads of the sea in times of old had prompted men of lively imagination to indulge their taste for the marvellous.

Gardner's description of the cemeteries laid open by the waves reminds us of the scene which has been so well depicted by Bewick *, and of which numerous points on the same coast might have suggested the idea. On the verge of a cliff, which the sea has undermined, are represented the unshaken tower and western end of an abbey. The eastern aisle is gone, and the pillars of the cloister are soon to follow. The waves have almost isolated the promontory, and invaded the cemetery, where they have made sport with the mortal relics, and thrown up a skull upon the beach. In the foreground is seen a broken tombstone, erected, as its legend tells " to *perpetuate* the memory of one whose name is obliterated, as is that of the county for which he was " Custos Rotulorum." A cormorant is perched on the monument, defiling it, as if to remind some moraliser, like Hamlet, of " the base uses " to which things sacred may be turned. Had this excellent artist desired to satirise certain popular theories of geology, he might have inscribed the stone to the memory of some philosopher who taught " the permanency of

* History of British Birds, vol. ii. p. 220. Ed. 1821.

existing continents"—"the era of repose"—"the impotence of modern causes."

South of Dunwich are two cliffs, called Great and Little Cat Cliff. That which bears the name of Great has become the smaller of the two, and is only fifteen feet high, the more elevated portion of the hill having been carried away; on the other hand, the Lesser Cat Cliff has gained in importance, for the sea has here been cutting deeper into a hill which slopes towards it. But at no distant period, the ancient names will again become appropriate, for at Great Cliff the base of another hill will soon be reached, and at Little Cat Cliff the sea will, at about the same time, arrive at a valley.

The incursions of the sea at Aldborough were formerly very destructive, and this borough is known to have been once situated a quarter of a mile east of the present shore. The inhabitants continued to build farther inland, till they arrived at the extremity of their property, and then the town decayed greatly; but two sand-banks, thrown up at a short distance, now afford a temporary safeguard to the coast. Between these banks and the present shore, where the current now flows, the sea is twenty-four feet deep on the spot where the town formerly stood.

Continuing our survey of the Suffolk coast to the southward, we find that the cliffs of Bawdsey and Felixtow are foundering slowly, and that the point on which Landguard Fort is built suffers gradual decay. It appears that, within the memory of persons now living, the Orwell river continued its course in a more direct line to the sea, and entered to the north instead of the south of the low bank on which the fort last mentioned is built.

Essex. — Harwich, in Essex, stands on an isthmus, which will probably become an island in little more than half a century; for the sea will then have made a breach near Lower Dover Court, should it continue to advance as rapidly as it has done during the last fifty years. Within ten years, there was a considerable space between the battery at Harwich, built twenty-three years ago, and the sea; part of the fortification has already been swept away, and the rest overhangs the water. Since the year 1807, a field called the Vicar's Field, which belonged to the living of Harwich, has been totally annihilated.*

At Walton Naze, in the same county, the cliffs, composed of London clay, capped by the shelly sands of the crag, reach the height of about 100 feet, and are annually undermined by the waves. The old church-yard of Walton has been washed away, and the cliffs to the south are constantly disappearing.

Kent. — *Isle of Sheppey.* — On the coast bounding the estuary of the Thames, there are numerous examples both of the gain and loss of land. The Isle of Sheppey, which is now about six miles long by four in breadth, is composed of London clay. The cliffs on the north, which are from sixty to eighty feet high, decay rapidly, fifty acres having been lost within the last twenty years. The church at Minster, now near the coast, is said to have been in the middle of the island fifty years ago†; and it has been conjectured that, at the present rate of destruction, the whole isle will be annihilated in about half a century. On the coast of the mainland to the east of Sheppey is Herne Bay; a place still retaining the name of a bay, although it is no longer

* On authority of Dr. Mitchell, F. G. S.

† For this information I am indebted to W. Gunnel, Esq.

appropriate, as the waves and currents have swept away the ancient headlands. There was formerly a small promontory in the line of the shoals where the present pier is built, by which the larger bay was divided into two, called the Upper and Lower.*

Still farther east stands the church of Reculver, upon a cliff composed of clay and sand, about twenty feet high. Reculver (Regulvium), was an important military station in the time of the Romans, and appears, from Leland's account, to have been, so late as Henry VIII.'s reign, nearly one mile distant from the sea. In the "Gentleman's Magazine", there is a view of it, taken in 1781, which still represents a considerable space as intervening between the north wall of the churchyard and the cliff.† Some time before the

Fig. 16.

View of Reculver Church, taken in the year 1781.

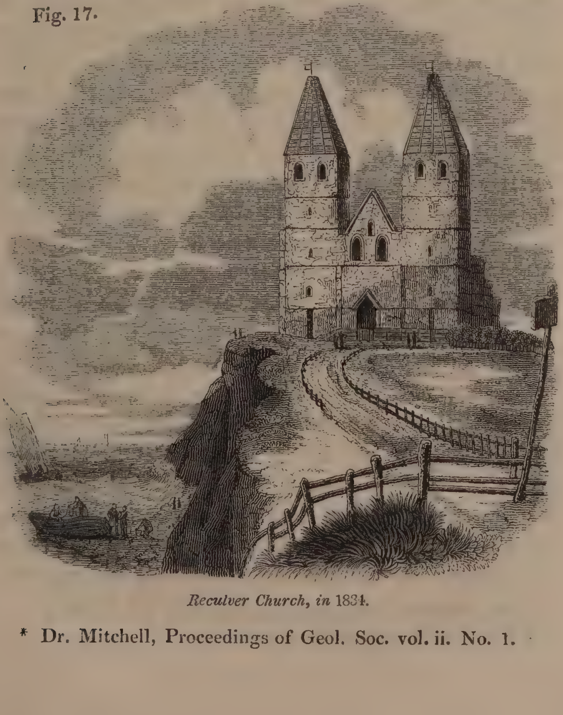
1. Isle of Sheppey.
2. Ancient chapel now destroyed. The cottage between this chapel and the cliff was demolished by the sea, in 1782.

* On the authority of W. Richardson, Esq., F.G.S.

† Vol. ii. New Series, 1809, p. 801.

year 1780, the waves had reached the site of the ancient Roman camp, or fortification, the walls of which had continued for several years after they were undermined to overhang the sea, being firmly cemented into one mass. They were eighty yards nearer the sea than the church, and they are spoken of in the "Topographica Britannica" in the year 1780, as having recently fallen down.* In 1804, part of the churchyard with some adjoining houses was washed away, and the ancient church, with its two lofty spires, a well known land mark, was dismantled and abandoned as a place of worship. It is still standing (1834), but

Fig. 17.



Reculver Church, in 1834.

* Dr. Mitchell, Proceedings of Geol. Soc. vol. ii. No. 1.

would probably have been annihilated ere this, had not the force of the waves been checked by an artificial causeway of stones and large wooden piles driven into the sands to break the force of the waves.*

Isle of Thanet.— The Isle of Thanet was, in the time of the Romans, separated from the rest of Kent by a navigable channel through which the Roman fleets sailed on their way to and from London. Bede describes this small estuary as being, in the beginning of the eighth century, three furlongs in breadth; and it is supposed that it began to grow shallow about the period of the Norman conquest. It was so far silted up in the year 1485, that an act was then obtained to build a bridge across it; and it has since become marsh land with small streams running through it. On the coast, Bedlam Farm, belonging to the hospital of that name, has lost eight acres in the last twenty years, the land being composed of chalk from forty to fifty feet above the level of the sea. It has been computed, that the average waste of the cliff between the North Foreland and the Reculvers, a distance of about eleven miles, is not less than two feet per annum. The chalk cliffs on the south of Thanet, between Ramsgate and Pegwell Bay, have on an average lost three feet per annum for the ten last years (preceding 1830).

Goodwin Sands.— The Goodwin Sands lie opposite this part of the Kentish coast. They are about ten miles in length, and are in some parts three, and in others seven miles distant from the shore; and, for a certain space, are laid bare at low water. That they are a remnant of land, and not "a mere accumulation of sea sand," as Rennell imagined†, may be presumed

* Dr. Mitchell, Proceedings of Geol. Soc. vol. ii. No. 1.

† Geog. of Herod. vol. ii. p. 326.

from the fact that, when the erection of a lighthouse on this shoal was in contemplation by the Trinity Board in the year 1817, it was found, by borings, that the bank consisted of fifteen feet of sand, resting on blue clay. An obscure tradition has come down to us, that the estates of Earl Goodwin, the father of Harold, who died in the year 1053, were situated here, and some have conjectured that they were overwhelmed by the flood mentioned in the Saxon chronicle, *sub anno* 1099. The last remains of an island, consisting, like Sheppey, of clay, may perhaps, have been carried away about that time.

There are other records of waste in the county of Kent, as at Deal; and at Dover, where Shakspeare's cliff, composed entirely of chalk, has suffered greatly, and continually diminishes in height, the slope of the hill being towards the land. About the year 1810 there was an immense land-slip from this cliff, by which Dover was shaken as if by an earthquake, and a still greater one in 1772.*

Straits of Dover.—In proceeding from the northern parts of the German Ocean towards the Straits of Dover, the water becomes gradually more shallow, so that in the distance of about two hundred leagues we pass from a depth of 120, to that of 58, 38, 24, and 18 fathoms. In the same manner the English Channel deepens progressively from Dover to its entrance, formed by the Land's End of England, and the Isle of Ushant on the Coast of France; so that the strait between Dover and Calais may be said to part two seas.†

* Dodsley's Ann. Regist. 1772.

† Stevenson on the Bed of the German Ocean. — Ed. Phil. Journ., No. v. p. 45.

Whether England was formerly united with France has often been a favourite subject of speculation; and in 1753 a society at Amiens proposed this as a subject of a prize essay, which was gained by the celebrated Desmarest, then a young man He founded his principal arguments on the identity of composition of the cliffs on the opposite sides of the channel, on a submarine chain extending from Boulogne to Folkestone, only fourteen feet under low water, and on the identity of the noxious animals in England and France, which could not have swum across the Straits, and would never have been introduced by man. He also attributed the rupture of the isthmus to the preponderating violence of the current from the north.* It will hardly be disputed that the ocean might have effected a breach through the land which, in all probability once united this country to the Continent in the same manner as it now gradually forces a passage through rocks of the same mineral composition, and often many hundred feet high, upon the coast.

Although the time required for such an operation was probably very great, yet we cannot estimate it by reference to the present rate of waste on both sides of the Channel; for when, in the thirteenth century the sea burst through the isthmus of Staveren, which formerly united Friesland with North Holland, it opened, in about one hundred years, a strait more than half as wide as that which divides England from France, after which the dimensions of the new channel remained almost stationary. The greatest depth of the straits between Dover and Calais is twenty-nine fathoms, which exceeds only by one fathom the

* Cuvier, Eloge de Desmarest.

greatest depth of the Mississippi at New Orleans. If the moving column of water in the great American river, which, as was before mentioned, does not flow rapidly, can maintain an open passage to that depth in its alluvial accumulations, still more might a channel of the same magnitude be excavated by the resistless force of the tides and currents of "the ocean stream,"

ποταμοιο μεγα σθενος Ωκεανοιο.

In framing these speculations, however, we must not overlook the great effects which particular combinations of causes might produce without violence. The chalk supposed in this instance to have been removed, was of itself a marine deposit, and must at some period have emerged from the deep. It may have been upraised gradually, as the coast of Sweden, with the bed of the adjacent ocean and Baltic sea, are now rising*; or there may have been oscillations of level in the lands once connecting France and England. In that case, and especially if the movements were slow, a great amount of excavation may have been produced by a comparatively feeble power exerted by waves and currents cutting through successive portions of the chalk as it emerged. And here I may mention, that strata of chalky rubble and sand found at the base of the cliffs near Dover and Brighton, seem to indicate some changes in the relative level of sea and land since our coasts acquired a considerable part of their actual height and contour.†

At Folkestone, the sea undermines the chalk and subjacent strata. About the year 1716 there was a remarkable sinking of a track of land near the sea, so that houses became visible at points near the shore

* See Book ii. chap. 17. † See Book iv. chap. 22.

from whence they could not be seen previously. In the description of this subsidence in the Philosophical Transactions, it is said, "that the land consisted of a solid stony mass (chalk), resting on wet clay (gault), so that it slid forwards towards the sea, just as a ship is launched on tallowed planks." It is also stated that, within the memory of persons then living, the cliff there had been washed away to the extent of ten rods.*

Encroachments of the sea at Hythe are also on record; but between this point and Rye there has been a gain of land within the times of history; the rich level tract called Romney Marsh, or Dungeness, about ten miles in width and five in breadth, and formed of silt, having received great accession. It has been necessary, however, to protect it from the sea, from the earliest periods, by a wall. These additions of land are exactly opposite that part of the English Channel where the conflicting tide-waves from the north and south meet; for, as that from the north is, for reasons already explained, the most powerful, they do not neutralize each other's force till they arrive at this distance from the straits of Dover. Rye, on the south of this tract, was once destroyed by the sea, but it is now two miles distant from it. The neighbouring town of Winchelsea was destroyed in the reign of Edward I., the mouth of the Rother stopped up, and the river diverted into another channel. In its old bed an ancient vessel, apparently a Dutch merchantman, was recently found. It was built entirely of oak, and much blackened.†

* Phil. Trans., 1716.

† Edin. Journ. of Sci., No. xix. p. 56.

South Coast of England.—To pass over some points near Hastings, where the cliffs have wasted at several periods, we arrive at the promontory of Beachy Head. Here a mass of chalk, three hundred feet in length, and from seventy to eighty in breadth, fell, in the year 1813, with a tremendous crash; and similar slips have since been frequent.*

Sussex.— About a mile to the west of the town of Newhaven the remains of an ancient entrenchment are seen, on the brow of Castle Hill. This earth-work, supposed to be Roman, was evidently once of considerable extent and of an oval form, but the greater part has been cut away. The cliffs, which are undermined here, are high; more than one hundred feet of chalk being covered by tertiary clay and sand, from sixty to seventy feet in thickness. In a few centuries the last vestiges of the plastic clay formation on the southern borders of the chalk of the South Downs on this coast will be annihilated, and future geologists will learn, from historical documents, the ancient geographical boundaries of this group of strata in that direction. On the opposite side of the estuary of the Ouse, on the east of Newhaven harbour, a bed of shingle, composed of chalk flints, derived from the waste of the adjoining cliffs, had accumulated at Seaford for several centuries. In the great storm of November, 1824, this bank was entirely swept away, and the town of Seaford inundated. Another great beach of shingle is now forming from fresh materials.

The whole coast of Sussex has been incessantly encroached upon by the sea from time immemorial; and, although sudden inundations only, which over-

* Webster, Geol. Trans., vol. ii. p. 192.

whelmed fertile or inhabited tracts are noticed in history, the records attest an extraordinary amount of loss. During a period of no more than eighty years, there are notices of about *twenty* inroads, in which tracts of land of from twenty to *four hundred acres* in extent were overwhelmed at once; the value of the tithes being mentioned by Nicholas, in his Taxatio Ecclesiastica.* In the reign of Elizabeth, the town of Brighton was situated on that tract where the chain pier now extends into the sea. In the year 1665, twenty-two tenements had been destroyed under the cliff. At that period there still remained under the cliff 113 tenements, the whole of which were overwhelmed in 1703 and 1705. No traces of the ancient town are now perceptible, yet there is evidence that the sea has merely resumed its ancient position at the base of the cliffs, the site of the old town having been merely a beach abandoned by the ocean for ages.

Hampshire — Isle of Wight.—It would be endless to allude to all the localities on the Sussex and Hampshire coasts where the land has given way; but I may point out the relation which the geological structure of the Isle of Wight bears to its present shape, as attesting that the coast owes its outline to the continued action of the sea. Through the middle of the island runs a high ridge of chalk strata, in a vertical position, and in a direction east and west. This chalk forms the projecting promontory of Culver Cliff on the east, and of the Needles on the west; while Sandown Bay on the one side, and Compton Bay on the other, have been hollowed out of the softer sands and argillaceous strata, which are inferior to the chalk.

* Mantell, Geology of Sussex, p. 293.

The same phenomena are repeated in the Isle of Purbeck, where the line of vertical chalk forms the projecting promontory of Handfast Point; and Swanage Bay marks the deep excavation made by the waves in the softer strata, corresponding to those of Sandown Bay.

Hurst-Castle Bank. — The entrance of the channel called the Solent is becoming broader by the waste of the cliffs in Colwell Bay; it is crossed for more than two thirds of its width by the shingle bank of Hurst Castle, which is about seventy yards broad and twelve feet high, presenting an inclined plane to the west. This singular bar consists of a bed of rounded chalk flints, resting on a submarine argillaceous base. The flints and a few other pebbles, intermixed, are exclusively derived from the waste of Hordwell, and other cliffs to the westward, where tertiary strata, capped with a covering of chalk flints, from five to fifty feet thick, are rapidly undermined.

Storm of Nov. 1824. — In the great storm of November, 1824, this bank of shingle was moved bodily forwards for forty yards towards the north-east; and certain piles which served to mark the boundaries of two manors were found, after the storm, on the opposite side of the bar. At the same time many acres of pasture land were covered by shingle, on the farm of Westover, near Lymington.

The cliffs between Hurst Shingle Bar and the mouth of the Stour and Avon are undermined continually. Within the memory of persons now living, it has been necessary thrice to remove the coast-road farther inland. The tradition, therefore, is probably true, that the church of Hordwell was once in the middle of that parish, although now very near the sea. The pro-

montory of Christ Church Head gives way slowly. It is the only point between Lymington and Poole Harbour, in Dorsetshire, where any hard stony masses occur in the cliffs. Five layers of large ferruginous concretions, somewhat like the septaria of the London clay, have occasioned a resistance at this point, to which we may ascribe this headland. In the mean time, the waves have cut deeply into the soft sands and loam of Poole Bay; and, after severe frosts, great land-slips take place, which, by degrees, become enlarged into narrow ravines, or chines, as they are called, with vertical sides. One of these chines near Boscomb, has been deepened twenty feet within a few years. At the head of each there is a spring, the waters of which have been chiefly instrumental in producing these narrow excavations, which are sometimes from 100 to 150 feet deep.

Isle of Portland. — The peninsulas of Purbeck and Portland are continually wasting away. In the latter, the soft argillaceous substratum (Kimmeridge clay) hastens the dilapidation of the superincumbent mass of limestone.

In 1665 the cliffs adjoining the principal quarries in Portland gave way to the extent of one hundred yards, and fell into the sea; and in December, 1734, a slide to the extent of 150 yards occurred on the east side of the isle, by which several skeletons, buried between slabs of stone, were discovered. But a much more memorable occurrence of this nature, in 1792, occasioned probably by the undermining of the cliffs, is thus described in Hutchins's History of Dorsetshire:— "Early in the morning the road was observed to crack: this continued increasing, and before two o'clock the ground had sunk several feet, and was in one con-

tinued motion, but attended with no other noise than what was occasioned by the separation of the roots and brambles, and now and then a falling rock. At night it seemed to stop a little, but soon moved again; and before morning, the ground, from the top of the cliff to the water-side, had sunk in some places fifty feet perpendicular. The extent of ground that moved was about *a mile and a quarter* from north to south, and six hundred yards from east to west."

Formation of the Chesil Bank. — Portland is connected with the main land by the Chesil Bank, a ridge of shingle about seventeen miles in length, and, in most places, nearly a quarter of a mile in breadth. The pebbles forming this immense barrier are chiefly of limestone; but there are many of quartz, jasper, chert, and other substances, all loosely thrown together. What is singular, they gradually diminish in size, from west to east — from the Portland end of the bank to that which attaches to the main land. The formation of this bar may probably be ascribed, like that of Hurst Castle, to a meeting of tides, or to a great eddy between the peninsula and the land. We have seen that slight obstructions in the course of the Ganges will cause, in the course of a man's life, slands many times larger than the whole of Portland, and which, in some cases, consist of a column of earth more than one hundred feet deep. In like manner we may expect the slightest impediment in the course of that tidal wave, which is sweeping away annually large tracts of our coast, to give rise to banks of sand and shingle many miles in length, if the transported materials be intercepted in their way to those submarine receptacles whither they are borne by the current. The gradual diminution in the size of the gravel as we proceed eastward might probably admit of expla-

nation, if the velocity of the tide or eddy at different points was ascertained; the rolled masses thrown up being largest where the motion of the water is most violent, or where they are deposited at the least distance from the rocks from which they were detached. The storm of 1824 burst over this bar with great fury, and the village of Chesilton, built upon the southern extremity of the bank, was overwhelmed, with many of the inhabitants. The fundamental rocks whereon the shingle rests are found at the depth of a few yards only below the level of the sea.

This same storm carried away part of the Breakwater, at Plymouth, and huge masses of rock from two to five tons in weight, were lifted from the bottom of the weather side, and rolled fairly to the top of the pile. One block of limestone, weighing seven tons, was washed round the western extremity of the Breakwater, and carried 150 feet.* It was in the same month, and also during a spring-tide, that a great flood is mentioned on the coasts of England, in the year 1099. Florence of Worcester says, "On the third day of the nones of Nov. 1099, the sea came out upon the shore, and buried towns and men very many, and oxen and sheep innumerable." We also read in the Saxon Chronicle, already cited for the year 1099, "This year eke on St. Martin's mass day, the 11th of Novembre, sprung up so much of the sea flood, and so myckle harm did, as no man minded that it ever afore did, and there was the ylk day a new moon."

Dorsetshire — Devonshire — Cornwall. — At Lyme Regis, in Dorsetshire, the "Church Cliffs," as they are called, consisting of lias about one hundred feet in height, have gradually fallen away, at the rate of one

* De la Beche, Geol. Man. p. 82.

yard a year, since 1800.* The cliffs of Devonshire and Cornwall, which are chiefly composed of hard rocks, decay less rapidly. Near Penzance in Cornwall, there is a projecting tongue of land, called the "Green," formed of granitic sand, from which more than thirty acres of pasture land have been gradually swept away in the course of the last two or three centuries.† It is also said that St. Michael's Mount, now an insular rock, was formerly situated in a wood several miles from the sea; and its old Cornish name (Caraclowse in Cowse) signifies, according to Carew, the Hoare Rock in the Wood.‡ Between the Mount and Newlyn there is seen under the sand black vegetable mould, full of hazel nuts, and the branches, leaves, roots, and trunks of forest trees, all of indigenous species. This vegetable stratum has been traced seaward as far as the ebb permits, and seems to indicate some ancient estuary on that shore.

Tradition of loss of land in Cornwall. — The oldest historians mention a celebrated tradition in Cornwall, of the submersion of the Lionnesse, a country which formerly stretched from the Land's End to the Scilly Islands. The tract, if it existed, must have been thirty miles in length, and perhaps ten in breadth. The land now remaining on either side is from two hundred to three hundred feet high; the intervening sea about three hundred feet deep. Although there is no evidence for this romantic tale, it probably origin-

* This ground was measured by Dr. Carpenter of Lyme, in 1800, and again in 1829, as I am informed by Miss Mary Anning of Lyme, well known by her discoveries in fossil remains.

† Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 129.

‡ Ibid. p. 135.

ated in some catastrophe occasioned by former inroads of the Atlantic upon this exposed coast.*

West coast of England. — Having now brought together an ample body of proofs of the destructive operations of the waves, tides, and currents, on our eastern and southern shores it will be unnecessary to enter into details of changes on the western coast, for they present merely a repetition of the same phenomena, and in general on an inferior scale. On the borders of the estuary of the Severn the flats of Somersetshire and Gloucestershire have received enormous accessions, while, on the other hand, submarine forests on the coast of Cheshire and Lancashire indicate the overflowing of alluvial tracts. Since the year 1764, the coast of Cheshire between the rivers Mersey and Dee has lost many hundred yards, and some affirm more than half a mile, by the advance of the sea upon abrupt cliffs of red clay and marls. Within the period above mentioned several light-houses have been successively abandoned.† There are traditions in Pembrokeshire‡ and Cardiganshire § of far greater losses of territory than that which the Lionnesse tale of Cornwall pretends to commemorate. They are all important, as demonstrating that the earliest inhabitants were familiar with the phenomenon of incursions of the sea.

Loss of land on the coast of France.—The French coast, particularly that of Brittany, where the tides rise to an extraordinary height, is the constant prey of

* Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 130.

† Stevenson, Jameson's Ed. new Phil. Journ. No. 8. p. 386.

‡ Camden, who cites Gyraldus, also Ray, "On the Deluge," Phys. Theol. p. 228.

§ Meyrick's Cardigan.

the waves. In the ninth century many villages and woods are reported to have been carried away, the coast undergoing great change whereby the hill of St. Michael was detached from the mainland. The parish of Bourgneuf, and several others in that neighbourhood, were overflowed in the year 1500. In 1735, during a great storm, the ruins of Palnel were seen uncovered in the sea.* A romantic tradition, moreover, has descended from the fabulous ages of the destruction of the south-western part of Brittany, whence we may probably infer some great inroad of the sea at a remote period.†

* Hoff, Geschichte, &c. vol. i. p. 49.

† Ibid. p. 48.

CHAPTER VII.

ACTION OF TIDES AND CURRENTS — *continued.*

Action of tides and currents, *continued* — Inroads of the sea upon the delta of the Rhine in Holland — changes in the arms of the Rhine — Estuary of the Bies Bosch, formed in 1421 — Zuyder Zee, in the 13th century — Islands destroyed — Delta of the Ems converted into a bay — Estuary of the Dollart formed (p. 58.) — Encroachment of the sea on the coast of Sleswick — On shores of North America — Tidal wave, called the Bore — Influence of tides and currents on the mean level of seas — Action of currents in inland lakes and seas — Baltic — Cimbrian deluge (p. 65.) — Straits of Gibraltar — No under-current there — Whether salt is precipitated in the Mediterranean — Waste of shores of Mediterranean.

Inroads of the sea at the mouths of the Rhine. — THE line of British coast considered in the preceding chapter offered no example of the conflict of two great antagonist forces; the entrance, on the one hand, of a river draining a large continent, and on the other, the flux and reflux of the tide, aided by a strong current. But when we pass over by the Straits of Dover to the Continent, and proceed northwards, we find an admirable illustration of such a contest, where the Rhine and the ocean are opposed to each other, each disputing the ground now occupied by Holland; the one striving to shape out an estuary, the other to form a delta. There was evidently a period when the river obtained the ascendency, when the shape of the

coast and set of the tides were probably very different; but for the last two thousand years, during which man has witnessed and actively participated in the struggle, the result has been in favour of the ocean; the area of the whole territory having become more and more circumscribed; natural and artificial barriers having given way, one after another; and many hundred thousand human beings having perished in the waves.

Changes in the arms of the Rhine. — The Rhine, after flowing from the Grison Alps, copiously charged with sediment, first purifies itself in the Lake of Constance, where a large delta is formed; then, swelled by the Aar and numerous other tributaries, it flows for more than six hundred miles towards the north: when, entering a low tract, it divides into two arms, north of Cleves, a little below the village of Pannerden — a point which must therefore be considered the head of its delta. In speaking of the delta I do not mean to assume that all that part of Holland which is comprised within the several arms of the Rhine can be called a delta in the strictest sense of the term; because some portion of the country thus circumscribed, as, for example, a part of Gelderland and Utrecht, consists of strata which may have been deposited in the sea before the Rhine existed. These older tracts may either have been raised like the Ullah Bund in Cutch, during the period when the sediment of the Rhine was converting a part of the sea into land, or they may have constituted islands previously.

When the river divides north of Cleves, the left arm takes the name of the Waal; and the right, retaining that of the Rhine, is connected, a little farther to the north, by an artificial canal with the river Yssel. Still lower down, the Rhine takes the name of the Leck, a

name which was given to distinguish it from another arm called the old Rhine, now sanded up, which passed by Utrecht and Leyden, to the sea at Catwyck. It is common, in all great deltas, that the principal channels of discharge should shift from time to time; but in Holland so many magnificent canals have been constructed, and have so diverted, from time to time, the course of the waters, that the geographical changes in this delta are endless, and their history, since the Roman era, forms a complicated topic of antiquarian research. The present head of the delta is about forty geographical miles from the nearest part of the gulf called the Zuyder Zee, and more than twice that distance from the general coast-line. The present head of the delta of the Nile is about eighty or ninety geographical miles from the sea; that of the Ganges, as we before stated, two hundred and twenty; and that of the Mississippi about one hundred and eighty, reckoning from the point where the Atchafalaya branches off, to the extremity of the new tongue of land in the Gulf of Mexico. But the comparative distance between the heads of deltas and the sea affords scarcely any data for estimating the relative magnitude of the alluvial tracts formed by their respective rivers. For the ramifications depend on many varying and temporary circumstances, and the area over which they extend does not hold any constant proportion to the volume of water in the river.

The Rhine therefore has at present three mouths. About two-thirds of its waters flow to the sea by the Waal, and the remainder is carried partly to the Zuyder Zee by the Yssel, and partly to the ocean by the Leck. As the whole coast to the south, as far as Ostend, and on the north, to the entrance of the Baltic

has, with few exceptions, from time immemorial, yielded to the force of the waves, it is evident that the delta of the Rhine, if it had advanced, would have become extremely prominent; and even if it had remained stationary, would long ere this have projected far beyond the rounded outline of the coast, like that strip of land already described, at the mouth of the Mississippi. But we find, on the contrary, that the islands which skirt the coast have not only lessened in size, but in number also, while great bays have been formed in the interior by incursions of the sea. I shall confine myself to the enumeration of some of the leading facts, in confirmation of these views, and begin with the southernmost part of the delta, where the Waal enters, which is at present united with the Meuse, in the same manner as an arm of the Po, before mentioned, has become confluent with the Adige. The Meuse itself had once a common embouchure with the Scheldt, by Sluys and Ostburg, but this channel was afterwards sanded up, as were many others between Walcheren, Beveland, and other islands, at the mouths of these rivers. The new accessions were almost all within the coast line, and were far more than counterbalanced by inroads of the sea, whereby large tracts of land, and dunes of blown sand, together with towns and villages, were swept away between the fourteenth and eighteenth centuries. Besides parts of Walcheren, Beveland, and several populous districts in Kadzand, the island Orisant was in the year 1658 entirely annihilated.

Inroads of the sea in Holland. — One of the most memorable irruptions occurred in 1421, where the tide, pouring into the mouth of the united Meuse and Waal, burst through a dam in the district named

Bergse-Veld, and overflowed seventy-two villages, forming a large sheet of water called the Bies Bosch. Thirty-five of the villages were irretrievably lost, and no vestige, even of their ruins, was afterwards seen. The rest were redeemed, and the site of the others, though still very generally represented on maps as an estuary, has in fact been gradually filled up by alluvial deposits, and is now, as I am informed by Professor Moll, an immense plain, yielding abundant crops of hay, though still uninhabited. To the north of the Meuse is a long line of shore covered with sand dunes, where great encroachments have taken place from time to time, in consequence chiefly of the prevalence of south-easterly winds which blow down the sands towards the sea. The church of Scheveningen, not far from the Hague, was once in the middle of the village, and now stands on the shore; half the place having been overwhelmed by the waves in 1570. Catwyck, once far from the sea, is now upon the shore; two of its streets having been overflowed, and land torn away to the extent of two hundred yards in 1719. It is only by aid of embankments, that Petten, and several other places farther north, have been defended against the sea.

Formation of the Zuyder Zee and Straits of Staveren. — Still more important are the changes which have taken place on the coast opposite the right arm of the Rhine, or the Yssel, where the ocean has burst through a large isthmus, and entered the inland lake Flevo, which, in ancient times, was, according to Pomponius Mela, formed by the overflowing of the Rhine over certain low lands. It appears that, in the time of Tacitus, there were several lakes in the present site of the Zuyder Zee, between Friesland and Holland. The

successive inroads by which these, and a great part of the adjoining territory, were transformed into a great gulf, began about the commencement, and were completed towards the close of the thirteenth century. Alting gives the following relation of the occurrence, drawn from manuscript documents of contemporary inhabitants of the neighbouring provinces. In the year 1205, the island now called Wieringen, to the south of the Texel, was still a part of the mainland, but during several high floods, of which the dates are given, ending in December, 1251, it was separated from the continent. By subsequent incursions, the sea consumed great parts of the rich and populous isthmus, a low tract which stretched on the north of Lake Flevo, between Staveren in Friesland, and Medemblick in Holland, till at length a breach was completed about the year 1282, and afterwards widened. Great destruction of land took place when the sea first broke in, and many towns were swept away; but there was afterwards a reaction to a certain extent, large tracts at first submerged having been gradually redeemed. The new straits south of Staveren are more than half the width of those of Dover, but are very shallow, the greatest depth not exceeding two or three fathoms. The new bay is of a somewhat circular form, and between *thirty* and *forty* miles in diameter. How much of this space may formerly have been occupied by Lake Flevo, is unknown.

Destruction of Islands. — A series of islands stretching from the Texel to the mouths of the Weser and Elbe, are evidently the last relics of a tract once continuous. They have greatly diminished in size, and have lost about a third of their number since the time

of Pliny; for that naturalist counted twenty-three islands between the Texel and Eider, whereas there are now only sixteen, including Heligoland and Neuwerk.* Heligoland, at the mouth of the Elbe, began in the year 800 to be much consumed by the waves. In the years 1300, 1500, and 1649, other parts were swept away, till at last only a rock of red marl (of the keuper formation of the Germans), about 200 feet high, and some low ground remained. Since 1770, a current has cut a passage no less than ten fathoms deep through this remaining portion, and has formed two islands, Heligoland and Sandy Island. The fact of the new channel being laid down in all the charts as sixty feet deep is important, as showing the excavating power of marine currents under favourable circumstances. On the other hand some few islands have extended their bounds in one direction, or become connected with others, by the sanding-up of channels; but even these, like Juist, have generally given way as much on the north towards the sea as they have gained on the south, or land side.

The Dollart formed. — While the delta of the Rhine has suffered so materially from the movements of the ocean, it can hardly be supposed that minor rivers on the same coast should have been permitted to extend their deltas. It appears, that in the time of the Romans there was an alluvial plain of great fertility, where the Ems entered the sea by three arms. This low country stretched between Groningen and East Friesland, and sent out a peninsula to the north-east towards Emden. A flood, in 1277, first destroyed part of the peninsula. Other inundations followed at differ-

* Hoff, vol. i. p. 364. † Id. p. 57.

ent periods throughout the fifteenth century. In 1507, a part only of Torum, a considerable town, remained standing; and in spite of the erection of dams, the remainder of that place, together with market-towns, villages, and monasteries, to the number of fifty, were finally overwhelmed. The new gulf, which was called the Dollart, although small in comparison to the Zuyder Zee, occupied no less than six square miles at first; but part of this space was, in the course of the two following centuries, again redeemed from the sea. The small bay of Leybucht, farther north, was formed in a similar manner in the thirteenth century; and the bay of Harlbucht, in the middle of the sixteenth. Both of these have since been partially reconverted into dry land. Another new estuary, called the Gulf of Jahde, near the mouth of the Weser, scarcely inferior in size to the Dollart, has been gradually hollowed out since the year 1016, between which era and 1651 a space of about four square miles has been added to the sea. The rivulet which now enters this inlet is very small; but Arens conjectures, that an arm of the Weser had once an outlet in that direction.

Coast of Sleswick. — Farther north we find so many records of waste on the western coast of Sleswick, as to lead us to anticipate, that, at no distant period in the history of the physical geography of Europe, Jutland may become an island, and the ocean may obtain a more direct entrance into the Baltic. So late as 1825 the sea made a breach and entered the Lym-Fiord, so that the northern extremity of Jutland was converted for a time into an island; but the passage is now closed again.*

* Malte-Brun, vol. viii. part ii. p. 572.

Destruction of Northstrand by the sea.— Northstrand, up to the year 1240, was, with the islands Sylt and Föhr, so nearly connected with the mainland as to appear a peninsula, and was called North Friesland, a highly cultivated and populous district. It measured from nine to eleven geographical miles from north to south, and six to eight from east to west. In the above-mentioned year it was torn asunder from the continent, and in part overwhelmed. The Isle of Northstrand, thus formed, was, towards the end of the sixteenth century, only four geographical miles in circumference, and was still celebrated for its cultivation and numerous population. After many losses, it still contained nine thousand inhabitants. At last, in the year 1634, on the evening of the 11th of October, a flood passed over the whole island, whereby 1300 houses, with many churches, were lost; fifty thousand head of cattle perished, and above six thousand men. Three small islets, one of them still called Northstrand, alone remained, which are now continually wasting.

Inroads of the sea on the eastern shores of North America.— After so many authentic details respecting the destruction of the coast in parts of Europe best known, it will be unnecessary to multiply examples of analogous changes in more distant regions of the world. It must not, however, be imagined that our own seas form any exception to the general rule. Thus, for example, if we pass over to the eastern coast of North America, where the tides rise to a great elevation, we find many facts attesting the incessant demolition of land. At Cape May, for example, on the north side of Delaware Bay, in the United States, the encroachment of the sea was shown by observ-

ations made consecutively for sixteen years, from 1804 to 1820, to average about nine feet a year *; and at Sullivan's Island, which lies on the north side of the entrance of the harbour of Charlestown, in South Carolina, the sea carried away a quarter of a mile of land in three years, ending in 1786.†

Tidal wave called "the Bore." — Before concluding my remarks on the action of the tides, I must not omit to mention the wave called "the Bore," which is sometimes produced in a river where a large body of water is made to rise suddenly, in consequence of the contraction of the channel. This wave terminates abruptly on the inland side; because the quantity of water contained in it is so great, and its motion so rapid, that time is not allowed for the surface of the river to be immediately raised by means of transmitted pressure. A tide wave thus rendered abrupt has a close analogy, observes Mr. Whewell, to the waves which curl over and break on a shelving shore. ‡

The Bore which enters the Severn, where the phenomenon is of almost daily occurrence, is sometimes nine feet high, and at spring tides rushes up the estuary with extraordinary rapidity. The same phenomenon is frequently witnessed in the principal branches of the Ganges, and in the Megna. "In the Hoogly, or Calcutta river," says Rennell, "the Bore commences at Hoogly Point, the place where the river first contracts itself, and is perceptible above Hoogly Town; and so quick is its motion, that it hardly employs four hours in travelling from one to the other, though the distance is nearly seventy miles.

* New Monthly Mag., vol. vi. p. 69. † Hoff, vol. i. p. 96.
‡ Phil. Trans., 1833, p. 204.

At Calcutta it sometimes occasions an instantaneous rise of five feet; and both here, and in every other part of its track, the boats, on its approach, immediately quit the shore, and make for safety to the middle of the river. In the channels, between the islands in the mouth of the Megna, the height of the Bore is said to exceed twelve feet; and is so terrific in its appearance, and dangerous in its consequences, that no boat will venture to pass at spring tide." * These waves may sometimes cause inundations, undermine cliffs, and still more frequently sweep away trees and land animals from low shores, so that they may be carried down, and ultimately imbedded in fluviatile or submarine deposits.

Relative level of different seas. — There is another question, in regard to the effects of tides and currents, not yet fully determined — how far they may cause the mean level of the ocean to vary at particular places. According to the French observations in Egypt the waters of the Red Sea maintain a constant elevation of between four and five fathoms above the neighbouring waters of the Mediterranean, at all times of the tide. Some have attributed this to a current setting up the Red Sea and raising its level. But Rennell has suggested that the Mediterranean may be lower than the Red Sea; because its loss by evaporation may not be compensated, especially at its eastern end, by the current setting in through the Straits of Gibraltar. It has also been imagined that there is an equal, if not greater diversity, in the relative levels of the Atlantic and Pacific, on the opposite sides of the isthmus of Panama. But the levellings recently car-

* Rennell, Phil. Trans. 1781.

ried across that isthmus by Mr. Lloyd, to ascertain the relative height of the Pacific Ocean at Panama, and of the Atlantic at the mouth of the river Chagres, have shown, that the difference of mean level between those oceans is not considerable, and contrary to expectation the difference which does exist is in favour of the greater height of the Pacific. According to the result of this survey, on which great dependence may be placed, the mean height of the Pacific is three feet and a half, or 3.52 above the Atlantic, if we assume the mean level of a sea to coincide with the mean between the extremes of the elevation and depression of the tides; for between the extreme levels of the greatest tides in the Pacific, at Panama, there is a difference of 27.44 feet; and at the usual spring tides 21.22 feet: whereas at Chagres this difference is only 1.16 feet, and is the same at all seasons of the year.

The tides, in short, in the Caribbean Sea are scarcely perceptible, not equalling those in some parts of the Mediterranean, whereas the rise is very high in the Bay of Panama; so that the Pacific is at high tide lifted up several feet above the surface of the Gulf of Mexico, and then at low water let down as far below it.* But astronomers are agreed that, on mathematical principles, the rise of the tidal wave above the mean level of a particular sea must be greater than the fall below it; and although the difference has been hitherto supposed insufficient to cause an appreciable error, it is, nevertheless, worthy of observation, that the error, such as it may be, would tend to reduce the small difference, now inferred, from the observations of Mr. Lloyd, to exist between the levels of the two oceans.

* Phil. Trans., 1830, p. 59.

ACTION OF CURRENTS IN INLAND LAKES AND SEAS.

In such large bodies of water as the North American lakes, the continuance of a strong wind in one direction often causes the elevation of the water, and its accumulation on the leeward side; and while the equilibrium is restoring itself, powerful currents are occasioned. In October 1833, a strong current in Lake Erie, caused partly by the set of the waters towards the outlet of the lake, and partly by the prevailing wind, burst a passage through the sandy isthmus called Long Point Peninsula, and soon excavated a channel more than nine feet deep and nine hundred feet wide. Its width and breadth have since increased, and a new and costly pier has been erected; for it is hoped that the event will permanently improve the navigation of Lake Erie for steam-boats.* In the Black Sea, also, although free from tides, we learn from Pallas that there is a sufficiently strong current to undermine the cliffs in many parts, and particularly in the Crimea.

The redundancy of river water in the Baltic, especially during the melting of ice and snow in spring, causes in general an outward current through the channel called the Cattegat. But after a continuance of north-westerly gales, especially during the height of the spring tides, the Atlantic rises; and, pouring a flood of water into the Baltic, commits dreadful devastations on the isles of the Danish Archipelago. This current even acts, though with diminished force, as far eastward as the vicinity of Dantzic.† Accounts written during the last ten centuries attest the wearing down

* M.S. of Capt. Bayfield, R.N.

† See examples in Hoff, vol. i. p. 73., who cites Pisansky.

of promontories on the Danish coast, the deepening of gulfs, the severing of peninsulas from the main land, and the waste of islands, while in several cases marsh land, defended for centuries by dikes, has at last been overflowed, and thousands of the inhabitants whelmed in the waves.

Thus the island Barsoe, on the coast of Sleswick, has lost, year after year, an acre at a time. The island Alsen suffers in like manner. The peninsula Zingst was converted into an island in 1625. There is a tradition that the isle of Rugen was originally torn by a storm from the main land of Pomerania: and it is known, in later times, to have lost ground, as in the year 1625, when a tract of land was carried away. Some of these islands consist of ancient alluvial accumulations, containing blocks of granite, which are also spread over the neighbouring main land. The Marsh Islands are mere banks, like the lands formed of the "warp" in the Humber, protected by dikes. Some of them, after having been inhabited with security for more than ten centuries, have been suddenly overwhelmed. In this manner, in 1216, no less than ten thousand of the inhabitants of the Eyderstede and Ditmarsch perished; and on the 11th of October, 1634, the islands and the whole coast, as far as Jutland, suffered by a dreadful deluge.

Cimbrian Deluge.—I have before enumerated the ravages of the ocean on the western shores of Sleswick, and there are memorials of a series of like catastrophes on the eastern coast of that peninsula. Jutland was the Cimbrica Chersonesus of the ancients, and was then evidently the theatre of similar calamities; for Florus says, "Cimbri, Theutoni, atque Tigurini, ab extremis Galliæ profugi, cùm terras eorum inun-

dasset Oceanus, novas sedes toto orbe quærebant."* Some have wished to connect this "Cimbrian Deluge" with the bursting of the isthmus between England and France, and with other supposed convulsions; but when we consider the fate of Heligoland and Northstrand, and the other terrific inundations in Jutland and Holstein since the Christian era, wherein thousands have perished, we need not resort to any such extraordinary catastrophes to account for the historical relation. The wave which in 1634 devastated the whole coast of Jutland committed such havoc, that we must be cautious how we reject hastily the traditions of like events on the coasts of Kent, Cornwall, Pembrokeshire, and Cardigan; for, however sceptical we may be as to the amount of territory destroyed, it is very possible that former inroads of the sea may have been greater on those shores than any witnessed in modern times.

Straits of Gibraltar.—It is well known that a powerful current sets constantly from the Atlantic into the Mediterranean, and its influence extends along the whole southern borders of that sea, and even to the shores of Asia Minor. Captain Smyth found, during his survey, that the central current ran constantly at the rate of from three to six miles an hour eastward into the Mediterranean, the body of water being three miles and a half wide. But there are also two lateral currents—one on the European, and one on the African side; each of them about two miles and a half broad, and flowing at about the same rate as the central stream. These lateral currents ebb and flow with the tide, setting alternately into the Mediterranean

* Lib. iii. cap. 3.

and into the Atlantic. The excess of water constantly flowing in is very great, and there is only one cause to which this can be attributed, the loss of water in the Mediterranean by evaporation. That the level of this sea should be considerably depressed by this means is quite conceivable, since we know that the winds blowing from the shores of Africa are hot and dry; and hygrometrical experiments recently made in Malta and other places, show that the mean quantity of moisture in the air investing the Mediterranean, is equal only to one half of that in the astmosphere of England. The temperature also of the great inland sea is upon an average higher, as was before stated, by $3\frac{1}{2}°$ of Fahrenheit, than the western part of the Atlantic ocean, which must greatly promote its evaporation. The Black Sea being situated in a higher latitude, and being the receptacle of rivers flowing from the north, is much colder, and its expenditure far less; accordingly, it does not draw any supply from the Mediterranean, but, on the contrary, contributes to it by a current flowing outwards, for the most part of the year, through the Dardanelles. The discharge, however, at the Bosphorus is so small when compared to the volume of water carried in by rivers as to imply a great amount of evaporation even in the Black Sea.

Whether salt be precipitated in the Mediterranean.—It is, however, objected, that evaporation carries away only fresh water, and that the current from the Atlantic is continually bringing in salt water: why, then, do not the component parts of the waters of the Mediterranean vary? or how can they remain so nearly the same as those of the ocean? Some have imagined that the excess of salt might be carried away by an under-current running in a contrary direction to the

superior; and this hypothesis appeared to receive confirmation from a late discovery that the water taken up about fifty miles within the Straits, from a depth of 670 fathoms, contained a quantity of salt *four times greater* than the water of the surface. Dr. Wollaston*, who analysed this water obtained by Captain Smyth, truly inferred that an under-current of such denser water, flowing outward, if of equal breadth and depth with the current near the surface, would carry out as much salt below as is brought in above, although it moved with less than one fourth part of the velocity, and would thus prevent a perpetual increase of saltness in the Mediterranean beyond that existing in the Atlantic. It was also remarked by others, that the result would be the same if, the swiftness being equal, the inferior current had only one fourth of the volume of the superior. At the same time there appeared reason to conclude that this great specific gravity was only acquired by water at immense depths; for two specimens of the water, taken at the distance of some hundred miles from the Straits, and at depths of 400, and even 450 fathoms, were found by Dr. Wollaston not to exceed in density that of many ordinary samples of sea-water. Such being the case, we can now prove that the vast amount of salt brought into the Mediterranean *does not* pass out again by the Straits; for it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the Capes of Trafalgar and Spartel, which are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on the side of Cape Spartel, is only 220

* On the water of the Mediterranean, by W. H. Wollaston, M.D., F.R.S. Phil. Trans., 1829, part i. p. 29.

fathoms. It is therefore evident that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than 220 fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar.

The idea of the existence of a counter-current, at a certain depth, first originated in the following circumstance: — M. De l'Aigle, commander of a privateer called the Phœnix, of Marseilles, gave chase to a Dutch merchant-ship, near Ceuta Point, and coming up with her in the middle of the gut, between Tariffa and Tangier, gave her one broadside, which directly sunk her. A few days after, the sunk ship, with her cargo of brandy and oil, was cast ashore near Tangier, which is at least four leagues to the westward of the place where she went down, and directly against the strength of the *central* current.* This fact, however, affords no evidence of an under-current, because the ship, when it approached the coast, would necessarily be within the influence of a lateral current, which, running westward twice every twenty-four hours, might have brought back the vessel to Tangier.

What, then, becomes of the excess of salt? — for this is an enquiry of the highest geological interest. The Rhone, the Po, and many hundred minor streams and springs, pour annually into the Mediterranean large quantities of carbonate of lime, together with iron, magnesia, silica, alumina, sulphur, and other mineral ingredients, in a state of chemical solution. To explain why the influx of this matter does not alter

* Phil. Trans., 1724.

the composition of this sea has never been regarded as a difficulty; for it is known that calcareous rocks are forming in the delta of the Rhone, in the Adriatic, on the coast of Asia Minor, and in other localities. Precipitation is acknowledged to be the means whereby the surplus mineral matter is disposed of, after the consumption of a certain portion in the secretions of testacea, zoophytes, and other marine animals. But before muriate of soda can, in like manner, be precipitated, the whole Mediterranean ought, it is said, to become as much saturated with salt as Lake Aral, the Dead Sea, or the brine-springs of Cheshire.

It is undoubtedly true, in regard to small bodies of water, that every particle must be fully saturated with muriate of soda before a single crystal of salt can be formed; such is probably the case in all natural salterns; such for example as those described by travellers as occurring on the western borders of the Black Sea, where extensive marshes are said to be covered by thin films of salt after a rapid evaporation of sea-water. The salt *étangs* of the Rhone, where salt has sometimes been precipitated in considerable abundance, have been already mentioned. But whether it be necessary that every part of a sea of enormous depth should be fully saturated before any precipitate can take place is a question of some difficulty. In the narrowest part of the Straits of Gibraltar, where they are about nine miles broad, between the Isle of Tariffa and Alcanzar Point, the depth varies from 160 to 500 fathoms: but between Gibraltar and Ceuta, Captain Smyth sounded to the enormous depth of 950 fathoms; where he found a gravelly bottom, with fragments of broken shells. Saussure sounded to the depth of two thousand feet, within a few yards of the shore, at Nice;

and M. Bérard has lately fathomed to the depth of more than six thousand feet in several places without reaching the bottom.*

The central abysses of this sea are, in all likelihood, at least as deep as the Alps are high; and, as at the depth of seven hundred fathoms only, water has been found to contain a proportion of salt four times greater than at the surface, we may presume that the excess of salt may be much greater at the depth of two or three miles. After evaporation, the surface water becomes impregnated with a slight excess of salt, and its specific gravity being thus increased, it instantly falls to the bottom, while lighter water rises to the top, or flows in laterally, being always supplied by rivers and the current from the Atlantic. The heavier fluid, when it arrives at the bottom, cannot stop if it can gain access to any lower part of the bed of the sea, not previously occupied by water of the same density. In this manner the bottom of the nethermost submarine abysses must annually receive new supplies of brine, while the water at the surface, being incessantly renewed by rivers and the current from the ocean, can never become saturated.

How far this accumulation of brine can extend before the inferior strata will part with any of their salt, and what difference in such a chemical process the immense pressure of the incumbent ocean might occasion, are questions which cannot be answered in the present state of science. There is also another curious topic of speculation; what changes may be effected by volcanic heat, so active in many parts of the bottom of the Mediterranean. A submarine hot-

* Bull. de la Soc. Géol. de France.—Résumé, p. 72. 1832.

spring or stufa would give rise to a new set of phenomena. Perhaps it may be said that their effect would only be to cause ascending and descending currents, and thereby to promote the intermixture of the upper and lower waters of the sea. A solfatara, or rent through which inflammable gases are continually escaping, might certainly convert sea-water into steam; and in this case salt would be precipitated in the space from which the steam was expelled. Additional supplies of water might then find their way into the fissure, being injected into every pore of the rock by the vast pressure of the incumbent ocean. If, by a repetition of this process, the cavity was filled with salt, other crystals of the same mineral would more easily be formed from a solution, and might then spread along the bottom of the sea. Yet even in this case it should seem that the fluid must first be fully saturated. It is certainly most difficult to explain on chemical principles how a deposit of salt may take place at the bottom of the Mediterranean, but it is nevertheles a fact that the waters of that sea, notwithstanding the constant influx of salt-water from the Atlantic, contain but a slight excess of muriate of soda above the ordinary waters of the ocean.

In regard to the probable origin of those continuous masses of rock-salt which we find in Poland, Hungary, Transylvania, and Spain, geologists have entertained very different opinions; but the theory which has obtained most favour in later times attributes them not to precipitation from an aqueous menstruum, but to sublimation from volcanic exhalations rising from below, which insinuate themselves into rents and vacuities, caused by the fracture and decomposition of rocks.

The straits of Gibraltar are said to become gradually wider by the wearing down of the cliffs on each side at many points; and the current sets along the coast of Africa so as to cause considerable inroads in various parts, particularly near Carthage. Near the Canopic mouth of the Nile, at Aboukir, the coast was greatly devastated in the year 1784, when a small island was nearly consumed. By a series of similar operations, the old site of the cities of Nicopolis, Taposiris, Parva, and Canopus, have become a sand-bank.*

Sand-Hills.—It frequently happens, where the sea is encroaching on a coast, that perpendicular cliffs of considerable height, composed of loose sand, supply, as they crumble away, large quantities of fine sand, which, being in mid-air when detached, are carried by the winds to great distances, covering the land or barring up the mouths of estuaries. This is exemplified in Poole Bay, in Hampshire, and in many points of the coast of Norfolk and Suffolk. But a violent wind will sometimes drift the sand of a sea beach, and carry it up with fragments of shells to great heights, as in the case of the sands of Barry, at the northern side of the estuary of the Tay, where hills of this origin attain the height of 140 feet.

On the coast of France and Holland long chains of these dunes have been formed in many parts, and often give rise to very important geological changes, by damming up the mouths of estuaries, and preventing the free ingress of the tides, or free efflux of river water.

* Clarke's Travels in Europe, Asia, and Africa, vol. iii. pp. 340. and 363. 4th edition.

CHAPTER VIII.

REPRODUCTIVE EFFECTS OF TIDES AND CURRENTS.

Reproductive effects of tides and currents — Silting up of estuaries does not compensate the loss of land on the borders of the ocean — Bed of the German Ocean (p. 81.) — Composition and extent of its sand-banks — Strata deposited by currents on the southern and eastern shores of the Mediterranean — Transportation by currents of the sediment of the Amazon, Orinoco, and Mississippi (p. 84.) — Stratification.

From the facts enumerated in the last chapter, it appears that, on the borders of the ocean, currents and tides co-operating with the waves of the sea are most powerful instruments in the destruction and transportation of rocks; and as numerous tributaries discharge their alluvial burden into the channel of one great river, so we find that many rivers deliver their earthy contents to one marine current, to be borne by it to a distance, and deposited in some deep receptacle of the ocean. The current not only receives this tribute of sedimentary matter from streams draining the land, but acts also itself on the coast, as does a river on the cliffs which bound a valley. The course of currents on the British shores is ascertained to be as tortuous as that of ordinary rivers. Sometimes they run between sand-banks, which consist of matter thrown down at certain points where the velocity of the stream had been retarded; but it very frequently happens, that as

in a river one bank is made of low alluvial gravel, while the other is composed of some hard and lofty rock constantly undermined, so the current, in its bends, strikes here and there upon a coast, which then forms one bank, while a shoal under water forms the other. If the coast, be composed of solid materials, it yields slowly; so also if it be of great height, for in that case a large quantity of matter must be removed before the sea can penetrate to any distance. But the openings where rivers enter are generally the points of least resistance, and it is here, therefore, that the ocean makes the widest and deepest breaches.

A current alone cannot shape out and keep open an estuary, because it holds in suspension, like the river, during certain seasons of the year, a large quantity of sediment; and where the waters, flowing in opposite directions, meet, this matter subsides. For this reason, in inland seas, and even on the borders of the ocean, where the rise of the tide happens to be slight, it is scarcely possible to prevent a harbour from silting up; and it is often expedient to carry out a jetty beyond the point where the marine current and the river neutralize each other's force; for beyond this point a free channel is maintained by the superior strength of the current.

Estuaries, how formed. — The formation and keeping open of large estuaries are due to the *combined influence* of the tidal currents and rivers; for when the tide rises, a large body of water suddenly enters the mouth of the river, where, becoming confined within narrower bounds, while its momentum is not destroyed, it is urged on, and, having to pass through a contracted channel, rises and runs with increased velocity, just as a stream, when it reaches the arch of a bridge scarcely

large enough to give passage to its waters, rushes with a steep fall through the arch. During the ascent of the tide, a body of fresh water, flowing down from the higher country, is arrested in its course for several hours; and thus a large lake of brackish water is accumulated, which, when the sea ebbs, is let loose, as on the removal of an artificial sluice or dam. By the force of this retiring water, the alluvial sediment both of the river and of the sea is swept away, and transported to such a distance from the mouth of the estuary, that a small part only can return with the next tide.

It sometimes happens, that during a violent storm a large bar of sand is suddenly made to shift its position, so as to prevent the free influx of the tides, or efflux of river water. Thus about the year 1500 the sands at Bayonne were suddenly thrown across the mouth of the Adour. That river, flowing back upon itself, soon forced a passage to the northward, along the sandy plain of Capbreton, till at last it reached the sea at Boucau, at the distance of *seven leagues* from the point where it had formerly entered. It was not till the year 1579 that the celebrated architect, Louis de Foix, undertook, at the request of Henry III., to re-open the ancient channel, which he at last effected with great difficulty. *

Tides in Estuaries. — In the estuary of the Thames at London, and in the Gironde, the tide flows five hours and ebbs seven, and in all estuaries the water requires a longer time to run down than up; so that the preponderating force is always in the direction

* Nouvelle Chronique de la Ville de Bayonne, pp. 113. 139.

which tends to keep open a deep and broad passage. But as both the river and the tidal current are ready to part with their sediment whenever their velocity is checked, there is naturally a tendency in all estuaries to silt up partially, since eddies, and backwaters, and points where opposing streams meet, are very numerous, and constantly change their position.

Silting up of estuaries does not compensate for loss of coasts. — Many writers have declared that the gain on our eastern coast, since the earliest periods of history, has more than counterbalanced the loss; but they have been at no pains to calculate the amount of loss, and have often forgotten that, while the new acquisitions are manifest, there are rarely any natural monuments to attest the former existence of the land that has been carried away. They have also taken into their account those tracts artificially recovered, which are often of great agricultural importance, and may remain secure, perhaps, for thousands of years, but which are only a few feet above the mean level of the sea, and are therefore exposed to be overflowed again by a small proportion of the force required to remove cliffs of considerable height on our shores. If it were true that the area of land annually abandoned by the sea in estuaries were equal to that invaded by it, there would still be no compensation *in kind*.

It will seem, at first sight, somewhat paradoxical, but it is nevertheless true, that the greater number of estuaries, although peculiarly exposed to the invasion of the sea, are usually contracting in size, even where the whole line of coast is giving way. But the fact is, that the inroads made by the ocean upon estuaries, although extremely great, are completed during periods of comparatively short duration; and in the intervals

between these irruptions, the mouths of rivers, like other parts of the coast, usually enjoy a more or less perfect respite. All the estuaries, taken together, constitute but a small part of a great line of coast; it is, therefore, most probable, that if our observations extend to a few centuries only, we shall not see any, and very rarely all, of this small part exposed to the fury of the ocean. The coast of Holland and Friesland, if studied for several consecutive centuries since the Roman era, would generally have led to the conclusion that the land was encroaching fast upon the sea, and that the aggrandizement within the estuaries far more than compensated the losses on the open coast. But when our retrospect embraces the whole period, an opposite inference is drawn: and we find that the Zuyder Zee, the Bies Bosch, Dollart, and Yahde, are modern gulfs and bays, and that these points have been the principal theatres of the retreat, instead of the advance, of the land. If we possessed records of the changes on our coast for several thousand years, they would probably present us with similar results; and although we have hitherto seen our estuaries, for the most part, become partially converted into dry land, and bold cliffs intervening between the mouths of rivers consumed by the sea, this has merely arisen from the accidental set of the currents and tides during a brief period.

The current which flows round from the north-west, and bears against the eastern coast of England, transports, as we have seen, materials of various kinds. It undermines and sweeps away the granite, gneiss, trap rocks, and sandstone of Shetland, and removes the gravel and loam of the cliffs of Holderness, Norfolk, and Suffolk, which are between fifty and two hundred

feet in height, and which waste at the rate of from one to six yards annually. It bears away the strata of London clay on the coast of Essex and Sheppey—consumes the chalk with its flints for many miles continuously on the shores of Kent and Sussex — commits annual ravages on the fresh-water beds, capped by a thick covering of chalk flints, in Hampshire, and continually saps the foundations of the Portland limestone. It receives, besides, during the rainy months, large supplies of pebbles, sand, and mud, which numerous streams from the Grampians, Cheviots, and other chains, send down to the sea. To what regions, then, is all this matter consigned? It is not retained in mechanical suspension by the waters of the sea, nor does it mix with them in a state of chemical solution, — it is deposited *somewhere*, yet certainly not in the immediate neighbourhood of our shores; for, in that case, there would soon be a cessation of the encroachment of the sea, and large tracts of low land, like Romney Marsh, would almost every where encircle our island.

As there is now a depth of water, exceeding thirty feet, in some spots where cities flourished but a few centuries ago, it is clear that the current not only carries far away the materials of the wasted cliffs, but removes also the ruins of many of the regular strata at the bottom of the sea.

So great is the quantity of matter held in suspension by the tidal current on our shores, that the waters are in some places artificially introduced into certain lands below the level of the sea; and by repeating this operation, which is called "warping," for two or three years, considerable tracts have been raised, in

the estuary of the Humber, to the height of about six feet. If a current, charged with such materials, meets with deep depressions in the bed of the ocean, it must often fill them up; just as a river, when it meets with a lake in its course, fills it gradually with sediment. But in the one case, the sheet of water is converted into land; whereas, in the other, a shoal only is raised, overflowed at high water, or at least by spring tides. The only records which we at present possess of the gradual shallowing of seas are confined, as might be expected, to estuaries, havens, and certain channels of no great depth; and to some inland seas, as the Baltic, Adriatic, and Arabian Gulf. It is only of late years, that accurate surveys and soundings have afforded data of comparison in very deep seas, of which future geologists will avail themselves.

An extraordinary gain of land is described to have taken place at the head of the Red Sea, the Isthmus of Suez having doubled in breadth since the age of Herodotus. In his time, and down to that of Arrian, Heroopolis was on the coast; now it is as far distant from the Red Sea as from the Mediterranean.* Suez in 1541 received into its harbour the fleet of Solyman II.; but it is now changed into a sand-bank. The country called Tehama on the Arabian side of the Gulf has increased from three to six miles since the Christian era. Inland from the present ports are the ruins of more ancient towns, which were once on the sea-shore, and bore the same names. It is said that the blown sand from the deserts supplies some

* Danville, Mém. sur l'Egypte, p. 108. — Von Hoff, vol. i. p. 390.

part of the materials of this new land, and that the rest is composed of shells and corals, of which the growth is very rapid.

Filling up of the German Ocean. — The German Ocean is deepest on the Norwegian side, where the soundings give 190 fathoms; but the mean depth of the whole basin may be stated at no more than thirty-one fathoms.* The bed of this sea is traversed by several enormous banks, one of which, occupying a central position, trends from the Frith of Forth, in a north-easterly direction, to a distance of 110 miles; others run from Denmark and Jutland upwards of 105 miles to the north-west; while the greatest of all, the Dogger Bank, extends for upwards of 354 miles from north to south. The whole superficies of these enormous shoals is equal to about one fifth of the whole area of the German Ocean, or to about one third of the whole extent of England and Scotland.† The average height of the banks measures, according to Mr. Stevenson, about seventy-eight feet; the upper portion of them consisting of fine and coarse siliceous sand, mixed with comminuted corals and shells.‡

It has been supposed by some writers, that these vast submarine hills are made up bodily of drift sand, and other loose materials, principally supplied from the waste of the English, Dutch, and other coasts. But the late survey of the North Sea, conducted by Captain Hewett, affords ground for suspecting that this opinion is very erroneous. If such immense mounds of sand and mud had been accumulated under

* Stevenson on the Bed of the German Ocean, or North Sea. — Ed. Phil. Journ. No. V. p. 44. 1820.

† Ibid., p. 47. ‡ Ibid.

the influence of currents, the same causes ought nearly to have reduced to a level the entire bottom of the German Ocean; instead of which some long narrow ravines are found to intersect the banks. One of these varies from seventeen to forty-four fathoms in depth, and has very precipitous sides: in one part, called the "Inner Silver Pits," it is fifty-five fathoms deep. The shallowest parts of the Doggerbank were found to be forty-two feet under water, except in one place, where the wreck of a ship had caused a shoal; so that we may suppose the currents, which vary in their velocity from a mile to two miles and a half per hour, to have power to prevent the accumulation of drift matter in places of less depth. It seems, then, that the great banks above alluded to, and the ravines which intersect them, cannot be due to the tides and currents now existing in this sea. They may, however, have been caused in great part by the movements of the ocean at some former period, when the bed of this sea, and the surface of the land adjoining, assumed its actual configuration.

Strata deposited by currents.— It appears extraordinary, that in some tracts of the sea, adjoining the coast of England, where we know that currents are not only sweeping along rocky masses, thrown down, from time to time, from the high cliffs, but also occasionally scooping out channels in the regular strata, there should exist fragile shells and tender zoophytes in abundance, which live uninjured by these violent movements. The ocean, however, is in this respect a counterpart of the land; and as, on the continents, rivers may undermine their banks, uproot trees, and roll along sand and gravel, while their waters are inhabited by testacea and fish, and their alluvial plains are

adorned with rich vegetation and forests, so the sea may be traversed by rapid currents, and its bed may here and there suffer great local derangement, without any interruption of the general order and tranquillity.

One important character in the formations produced by currents, is, the immense extent over which they may be the means of diffusing homogeneous mixtures for these are often co-extensive with a great line coast, and, by comparison with their deposits, the deltas of rivers must shrink into insignificance. In the Mediterranean, the same current which is rapidly destroying many parts of the African coast, between the Straits of Gibraltar and the Nile, preys also upon the delta of the Nile, and drifts the sediment of that great river to the eastward. To this source may be attributed the rapid accretions of land on parts of the Syrian shores where rivers do not enter.

It is the opinion of M. Girard, one of the scientific men who accompanied Napoleon's expedition to Egypt, and who were employed on the survey of the ancient canal of Amron, communicating between the Nile and the Red Sea, that the isthmus of Suez itself is merely a bar formed by the deposition of this current and of the Nile, and that the two seas were formerly united.* It is certain, as before stated, that the isthmus is daily gaining in width by the accession of fresh deposits on the shores of the Mediterranean.†

The ruins of ancient Tyre are now far inland, and those of ancient Sidon are two miles distant from the

* Description de l'Egypte, Mémoires, tom. i. p. 33.

† Quarterly Review, No. lxxxvi. p. 445.

coast, the modern town having been removed towards the sea.* But the south coast of Asia Minor affords far more striking examples of advances of the land upon the sea, where small streams co-operate with the current before mentioned. Captain Beaufort, in his Survey of that coast, has pointed out the great alterations effected on these shores since the time of Strabo, where havens are filled up, islands joined to the mainland, and where the whole continent has increased many miles in extent. Strabo himself, on comparing the outline of the coast in his time with its ancient state, was convinced, like our countryman, that it had gained very considerably upon the sea. The new-formed strata of Asia Minor consist *of stone*, not of loose, incoherent materials. Almost all the streamlets and rivers, like many of those in Tuscany and the south of Italy, hold abundance of carbonate of lime in solution, and precipitate travertin, or sometimes bind together the sand and gravel into solid sandstones and conglomerates: every delta and sand-bar thus acquires solidity, which often prevents streams from forcing their way through them, so that their mouths are constantly changing their position.†

Distribution of the sediment of the Amazon by currents. — Among the greatest deposits now in progress, and of which the distribution is chiefly determined by currents, we may class those between the mouths of the Amazon and the southern coast of North America. It has been before stated that a great current flows

* Hoff, vol. i. p. 253.

† Karamania, or a brief Description of the Coast of Asia Minor, &c. London, 1817.

along the coast of Africa, from the south, which, when it reaches the head of the Gulf of Guinea, and is opposed by the waters brought to the same spot by the Guinea current, streams off in a westerly direction, and pursues its rapid course quite across the Atlantic to the continent of South America. Here one portion proceeds along the northern coast of Brazil to the Caribbean Sea and the Gulf of Mexico. Captain Sabine found that this current was running with the astonishing rapidity of four miles an hour where it crosses the stream of the Amazon, which river preserves part of its original impulse, and has its waters not wholly mingled with those of the ocean at the distance of three hundred miles from its mouth.* The sediment of the Amazon is thus constantly carried to the north-west as far as to the mouths of the Orinoco, and an immense tract of swamp is formed along the coast of Guiana, with a long range of muddy shoals bordering the marshes, and becoming converted into land.† The sediment of the Orinoco is partly detained, and settles near its mouth, causing the shores of Trinidad to extend rapidly, and is partly swept away into the Caribbean Sea by the Guinea current. According to Humboldt, much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico. The rivers, also, which descend from the high platform of Mexico, between the mouths of the Norte and Tampico, when they arrive, swollen by tropical rains, at the edge of that platform, bear down an enormous quantity of rock and mud to the sea; but the

* Experiments to determine the Figure of the Earth, &c. p. 445.

† Lochead's Observations on the Nat. Hist. of Guiana. Edin. Trans., vol. iv.

current, setting across their mouths, prevents the growth of deltas, and preserves an almost uniform curve in that line of coast.* It must, therefore, exert a great transporting power, and it cannot fail to sweep away part of the matter which is discharged from the mouths of the Norte and the Mississippi.

Area over which strata may be formed by currents.— In regard to the distribution of sediment by currents, it may be observed, that the rate of subsidence of the finer mud carried down by every great river into the ocean, must be extremely slow; for the more minute the separate particles of mud, the slower will they sink to the bottom, and the sooner will they acquire what is called their terminal velocity. It is well known that a solid body, descending through a resisting medium, falls by the force of gravity, which is constant, but its motion is resisted by the medium more and more as its velocity increases, until the resistance becomes sufficient to counteract the further increase of velocity. For example, a leaden ball, one inch diameter, falling through air of density as at the earth's surface, will never acquire greater velocity than 260 feet per second, and, in water, its greatest velocity will be 8 feet 6 inches per second. If the diameter of the ball were $\frac{1}{100}$ of an inch, the terminal velocities in air would be 26 feet, and in water .86 of a foot per second.

Now, every chemist is familiar with the fact, that minute particles descend with extreme slowness through water, the extent of their surface being very great in proportion to their weight; and the resistance of the fluid depending on the amount of surface. A pre-

* This coast has been recently examined by Captain Vetch.— See also Bauza's new chart of the Gulf of Mexico.

cipitate of sulphate of baryta, for example, will sometimes require more than five or six hours to subside one inch *; while oxalate and phosphate of lime require nearly an hour to subside about an inch and a half and two inches respectively †, so exceedingly small are the particles of which these substances consist.

When we recollect that the depth of the ocean is supposed frequently to exceed three miles, and that currents run through different parts of that ocean at the rate of four miles an hour, and when at the same time we consider that some fine mud carried down by rivers, as well as the impalpable powder showered down by volcanos, may subside at the rate of only an inch per hour, we shall be prepared to find examples of the transportation of sediment over areas of indefinite extent.

It is not uncommon for the emery powder used in polishing glass to take more than an hour to sink one foot. Suppose mud, composed of particles twice as coarse, to fall at the rate of two feet per hour, and these to be discharged into that part of the Gulf Stream which preserves a mean velocity of three miles an hour for a distance of two thousand miles; in twenty-eight days these particles will be carried 2016 miles, and will have fallen only to a depth of 224 fathoms.

In this example, however, it is assumed that the current retains its superficial velocity at the depth of 224 fathoms, for which we have as yet no data. Experiments should be made to ascertain the rate of currents at considerable distances from the surface,

* On the authority of Mr. Faraday.

† On the authority of Mr. R. Phillips.

and the time taken by the finest river sediment to settle in sea-water of a given depth, and then the geologist may determine the area over which homogeneous mixtures may be simultaneously distributed in certain seas.

Stratification.— In regard to the internal arrangement of formations deposited in the deep sea by currents far from the land, we may infer that in them, as in deltas, there is usually a division into strata; for, in both cases, the accumulations are successive, and, for the most part, interrupted. The waste of cliffs on the British coast is almost entirely confined to the winter months; so that running waters in the sea, like those on the land, are periodically charged with sediment, and again become pure.

CHAPTER IX.

IGNEOUS CAUSES.

Changes of the inorganic world, *continued* — Igneous causes — Division of the subject — Distinct volcanic regions — Region of the Andes — System of volcanos extending from the Aleutian isles to the Moluccas (p. 99.) — Polynesian archipelago — Volcanic region extending from the Caspian Sea to the Azores — Former connection of the Caspian, Lake Aral, and Sea of Azof — Tradition of deluges on the shores of the Bosphorus, Hellespont, and Grecian isles (p. 104.) — Periodical alternation of earthquakes in Syria and Southern Italy — Western limits of the European region (p. 111.) — Earthquakes rarer and more feeble as we recede from the centres of volcanic action — Extinct volcanos not to be included in lines of active vents.

We have hitherto considered the changes wrought, since the times of history and tradition, by the continued action of aqueous causes on the earth's surface; and we have next to examine those resulting from igneous agency. As the rivers and springs on the land, and the tides and currents in the sea, have, with some slight modifications, been fixed and constant to certain localities from the earliest periods of which we have any records, so the volcano and the earthquake have, with few exceptions, continued, during the same lapse of time, to disturb the same regions. But as there are signs, on almost every part of our continent, of great

power having been exerted by running water on the surface of the land, and by waves, tides, and currents on cliffs bordering the sea, where, in modern times, no rivers have excavated, and no waves or tidal currents undermined—so we find signs of volcanic vents and violent subterranean movements in places where the action of fire has long been dormant. We can explain why the intensity of the force of aqueous causes should be developed in succession in different districts. Currents, for example, tides, and the waves of the sea, cannot destroy coasts, shape out or silt up estuaries, break through isthmuses, and annihilate islands, form shoals in one place and remove them from another, without the direction and position of their destroying and transporting power becoming transferred to new localities. Neither can the relative levels of the earth's crust, above and beneath the waters, vary from time to time, as they are admitted to have varied at former periods, and as it will be demonstrated that they still do, without the continents being, in the course of ages, modified, and even entirely altered, in their external configuration. Such events must clearly be accompanied by a complete change in the volume, velocity, and direction of the streams and land floods to which certain regions give passage. That we should find, therefore, cliffs where the sea once committed ravages, and from which it has now retired—estuaries where high tides once rose, but which are now dried up—valleys hollowed out by water, where no streams now flow, is no more than we should expect;—these and similar phenomena are the necessary consequences of physical causes now in operation; and, if there be no instability in the laws of nature, similar fluctuations must recur again and again in time to come.

But, however natural it may be that the force of running water in numerous valleys, and of tides and currents in many tracts of the sea, should now be *spent*, it is by no means so easy to explain why the violence of the earthquake and the fire of the volcano should also have become locally extinct, at successive periods. We can look back to the time when the marine strata, whereon the great mass of Etna rests, had no existence; and that time is extremely modern in the earth's history. This alone affords ground for anticipating that the eruptions of Etna will one day cease.

> Nec quæ sulfureis ardet fornacibus Ætna
> Ignea semper erit, *neque enim fuit ignea semper*,

are the memorable words which are put into the mouth of Pythagoras by the Roman poet, and they are followed by speculations as to the cause of volcanic vents shifting their positions. Whatever doubts the philosopher expresses as to the nature of these causes, it is assumed, as incontrovertible, that the points of eruption will hereafter vary, *because they have formerly done so.*

I have endeavoured to show, in former chapters, that this principle of reasoning has been too much set at naught by some modern schools of geology, which not only refuse to conclude that great revolutions in the earth's surface are now in progress, or that they will take place hereafter, *because* they have often been repeated in former ages, but even assume the improbability of such a conclusion, and throw the whole weight of proof on those by whom that doctrine is embraced.

Division of the subject.—Humboldt has defined

volcanic action to be "the influence exerted by the interior of a planet on its external covering *during the different stages of refrigeration.*" If we adopt the first part of this definition, without connecting it with the theory of secular refrigeration, or the cooling down of an original heated and fluid nucleus, we may then class under a general head all the subterranean phenomena, whether of volcanos, earthquakes, or those insensible movements of the land, by which, as will afterwards appear, large districts may be depressed or elevated, without convulsions. According to this view, I shall consider, first, the volcano; secondly, the earthquake; thirdly, the rising or sinking of land in countries where there are no volcanos or earthquakes; fourthly, the probable *causes* of the changes which result from subterranean agency.

It is a very general opinion, that earthquakes and volcanos have a common origin; for both are confined to certain regions, although the subterranean movements are least violent in the immediate proximity of volcanic vents, especially where the discharge of aëriform fluids and melted rock is made constantly from the same crater. But as there are particular regions, to which both the points of eruption and the movements of great earthquakes are confined, I shall begin by tracing out the geographical boundaries of some of these, that the reader may be aware of the magnificent scale on which the agency of subterranean fire is now simultaneously developed. Over the whole of the vast tracts alluded to, active volcanic vents are distributed at intervals, and most commonly arranged in a linear direction. Throughout the intermediate spaces there is abundant evidence that the subterranean fire is at work continuously, for the

ground is convulsed from time to time by earthquakes; gaseous vapours, especially carbonic acid gas, are disengaged plentifully from the soil; springs often issue at a very high temperature, and their waters are usually impregnated with the same mineral matters as are discharged by volcanos during eruptions.

DISTINCT REGIONS OF SUBTERRANEAN DISTURBANCE.

Region of the Andes. — Of these great regions, that of the Andes is one of the best defined. Respecting its southern extremity, we are still in need of more accurate information, doubts being entertained by some whether it extends into Tierra del Fuego. Captain Hall, however, had a distant view from his ship, in 1822, of appearances which seem clearly to indicate an eruption of a volcano placed near the Beagle Channel (50° 48′ S. lat., 68° W. long.). Several volcanos are said to exist in the Andes of Patagonia, and no less than nineteen points of eruption are well known in Chili, situated in a continuous line from south to north, and forming lofty mountains. The number may hereafter be greatly augmented when the country has been more carefully examined, and throughout a longer period. How long an interval of rest may entitle us to consider a volcano as extinct, is not easily determined; but we know that, in Ischia, there intervened, between two consecutive eruptions, a pause of *seventeen centuries;* and a much longer period, perhaps, elapsed between the eruptions of Vesuvius before the earliest Greek colonies settled in Campania, and the renewal of its activity in the reign of Titus. It will be necessary, therefore, to

wait for at least six times as many centuries as have elapsed since the discovery of America, before any one of the dormant craters of the Andes can be presumed to be entirely spent, unless where there are some *geological* proofs that the latest eruptions must have belonged to a remote era.

From the observations of Humboldt it appears, that all the volcanos of the Andes, whether extinct or active, have burst through basalts and trachytes, or through some igneous rocks of a porphyritic structure. All the loftiest summits of the range are composed of trachyte, with which abundance of obsidian is occasionally associated, and large accumulations of pumice and tuff, the latter formed of fragments of lava and cinders agglutinated together.

Villarica, in lat. 39° 8′ S., one of the principal of the Chilian volcanos, continues burning without intermission, and is so high that it may be distinguished at the distance of 150 miles. A year never passes in this province without some slight shocks of earthquakes; and about once in a century, or oftener, tremendous convulsions occur, by which, as will be afterwards seen, the land has been shaken from one extremity to the other; and continuous tracts, including part of the bed of the Pacific, have been permanently raised from one to twenty feet or more above their former level. Hot springs are numerous in this district, as well as springs of naphtha and petroleum, and mineral waters of various kinds.

If we pursue our course northwards, we find in Peru only one active volcano as yet known; but the province is so subject to earthquakes, that scarcely a week happens without a shock, and many of these

have been so considerable as to create great changes of the surface.

Proceeding farther north, we find the most considerable volcanos of the Andes situated in the province of Quito, where that chain attains its highest elevation. These volcanos, occurring between the second degree of south and the third degree of north lat., are, Cayambe, Cotopaxi, Pichincha, Antisana, L'Altar, and Tunguragua. The form of Cayambe, whose summit is crossed by the line of the equator, is that of a truncated cone, which rises to the immense height of 19,625 feet. The Indians of Lican have a tradition that the mountain called L'Altar, or Capac Urcu, which means "the chief," was once the highest of those near the equator, being higher than Chimborazo, but in the reign of Ouainia Abomatha, before the discovery of America, a prodigious eruption took place, which lasted eight years, and broke it down. The fragments of trachyte, says M. Boussingault, which once formed the conical summit of this celebrated mountain, are at this day spread over the plain.* Cotopaxi is the most lofty of all the South American volcanos which have been in a state of activity in modern times, its height being 18,858 feet; and its eruptions have been more frequent and destructive than those of any other mountain. It is a perfect cone, usually covered with an enormous bed of snow, which has, however, been sometimes melted suddenly during an eruption; as in Jan. 1803, for example, when the snows were dissolved in one night.

Deluges are often caused in the Andes by the liquefaction of great masses of snow, and sometimes by the

* Bull. de la Soc. Géol., tom. vi. p. 55.

rending open, during earthquakes, of subterranean cavities filled with water. In these inundations, fine volcanic sand, loose stones, and other materials which the water meets with in its descent are swept away, and a vast quantity of mud, called "moya," is thus formed and carried down into the lower regions. Mud derived from this source descended, in 1797, from the sides of Tunguragua, and filled valleys a thousand feet wide to the depth of six hundred feet, forming barriers by which rivers were dammed up, and lakes occasioned. In these currents and lakes of moya thousands of small fish are sometimes enveloped which, according to Humboldt, have lived and multiplied in subterranean cavities. So great a quantity of these fish were ejected from the volcano of Imbaburu in 1691, that fevers, which prevailed at the period, were attributed to the effluvia arising from the putrid animal matter.

In Quito, many important revolutions in the physical features of the country are said to have resulted, within the memory of man, from the earthquakes by which it has been convulsed. M. Boussingault declares his belief, that if a full register had been kept of all the convulsions experienced here and in other populous districts of the Andes, it would be found that the trembling of the earth had been incessant. The frequency of the movement, he thinks, is not due to volcanic explosions, but to the continual falling in of masses of rock which have been fractured and upheaved in a solid form at a comparatively recent epoch. According to the same author, the height of several mountains of the Andes has diminished in modern times.*

* Bull. de la Soc. Géol. de France, tom. vi. p. 56.

If we continue our investigations still farther to the north, we find in the same line three volcanos in the province of Pasto, and three others in that of Popayan. In the provinces of Guatimala and Nicaragua, which lie between the isthmus of Panama and Mexico, there are no less than twenty-one active volcanos, all of them contained between the tenth and fifteenth degrees of north latitude.

The great volcanic chain, after having thus pursued its course for several thousand miles from south to north, turns off in a side direction in Mexico, in the parallel of the city of that name, and is prolonged in a great platform, between the eighteenth and twenty-second degrees of north latitude. This high table land is said to owe its present form to the circumstance of an ancient system of valleys, in a chain of granitic mountains, having been filled up to the depth of many thousand feet, with various volcanic products. Five active volcanos traverse Mexico from west to east — Tuxtla, Orizaba, Popocatepetl, Jorullo, and Colima. Jorullo, which is in the centre of the great platform, is no less than 120 miles from the nearest ocean — an important circumstance, as showing that the proximity of the sea is not a necessary condition, although certainly a very general characteristic, of the position of active volcanos. The extraordinary eruption of this mountain, in 1759, will be described in the sequel. If the line which connects these five vents be prolonged, in a westerly direction, it cuts the volcanic group of islands, called the Isles of Revillagigedo.

To the north of Mexico there are three, or according to some five, volcanos, in the peninsula of California, but of these we have at present no detailed account. I have before mentioned the violent earthquakes which

in 1812 convulsed the valley of the Mississippi at New Madrid, for the space of three hundred miles in length. As this happened exactly at the same time as the great earthquake of Caraccas, it is probable that these two points are parts of one continuous volcanic region; for the whole circumference of the intervening Caribbean Sea must be considered as a theatre of earthquakes and volcanos. On the north lies the island of Jamaica, which, with a tract of the contiguous sea, has often experienced tremendous shocks; and these are frequent along a line extending from Jamaica to St. Domingo, and Porto Rico. On the south of the same basin the shores and mountains of Colombia are perpetually convulsed. On the west, is the volcanic chain of Guatimala and Mexico, before traced out; and on the east the West India isles, where, in St. Vincent's and Guadaloupe, are active vents.

Thus it will be seen that volcanos and earthquakes occur uninterruptedly, from Chili to the north of Mexico; and it seems probable, that they will hereafter be found to extend from Cape Horn to California, or even to New Madrid, in the United States — a distance upon the whole as great as from the pole to the equator. In regard to the western limits of the region, they lie deep beneath the waves of the Pacific, and must continue unknown to us. On the east they are not prolonged, except where they include the West Indian islands, to a great distance; for there seem to be no indications of volcanic disturbances in Guiana, Brazil, and Buenos Ayres.

Canada. — Although no volcanos have been discovered in the northern regions of the new continent, we have authentic accounts of frequent earthquakes in Canada, and some of considerable violence have


Volcanic Band,
of the
Molucca,
and
Sunda Islands.
Reduced from Maps of
Leopold von Buch.
100
110
120
130
20
10
0
10
Longitude East from Greenwich.
Pegu
Cambodia
Hainan
Camigen
Luzon
Aringnay
Manilla
Taal
Philippine Islands
Mindoro
Calamianes
Tablas
Masbate
Albay
Samar
Panay
Negros
Leyte
Bohol
Palawan
Balabac
Mindanao
Sanguil
Salibabo
Barren I.
Domel
Salanga
Tantalam
Nicobar Is.
Malay
Delli
Vol. of Allas
Hog I.
Nias I.
Sumatra
Singapore
Bintang
Linga
Po. Battooa
Berapi
Padang
Po. Sebeeroo
Gunong Penkalan
Good Fortune
N. Poggy
S. Poggy
Gunong Dempo
Banka
Billiton
Isles
Bencoolen
of
Sunda
Gt. Natuna
Mid. Anambas
Volcano
Sambas
Borneo
Benjermassin
Po. Laut
Maratuba
Celebes
Kemas
Booton
Morty
Gammacanore
Gilolo
Moluccas Islands
Wageeoo
New
Guinea
Ceram
Booro
Amboina
Banda
Volcano
Seroa
Nila
Batavia
Salak
Tegal
Merapi
Madura
Kangylang
Arjun
Lombook
Bally
Floris
Sumbawa
Volcano
Sandel Wood I.
Timor
Wetter
Ombay
Lomblem
Volcano
Volcanic Band,
of the
Greek Islands.
Andros
Tino
Zea
Syra
Thermia
Serpho
Paros
Naxia
Siphanto
Anti Paro
Argentiera
Milo
Policandro
Therasia
Santorin
Hydra

occurred, as that of 1663, hereafter to be described. A large part of the estuary of the St. Lawrence and the surrounding country has been shaken from time to time; and we learn from Captain Bayfield's Memoirs, that along the shores of the estuary and Gulf of St. Lawrence horizontal banks of recent shells appear at various heights, from ten to one hundred feet above high water mark, and inland beaches of sand and shingle with similar shells, as also elevated limestone rocks scooped out by the waves, and showing lines of lithodomous perforations, facts which indicate most clearly the successive upheaving of the land since the sea was inhabited by the existing species of testacea.*

Volcanic region from the Aleutian Isles to the Moluccas.—On a scale, which equals, or surpasses, that of the Andes, is another continuous line of volcanic action, which commences, on the north, with the Aleutian Isles in Russian America, and extends, first in an easterly direction for nearly two hundred geographical miles, and then southwards, without interruption, throughout a space of between 60° and 70° of latitude to the Moluccas, where it branches off in different directions both towards the east and north-west.† The northern extremity of this volcanic region is the Peninsula of Alaska in about the fifty-fifth degree of latitude. From thence the line is continued through the Aleutian or Fox Islands, to Kamtschatka. In that archipelago eruptions are frequent; and a new island rose in 1814, which, according to some reports, is three thousand

* Proceedings of Geol. Soc. No. i. vol. ii. and Trans. of Lit. Soc. of Quebec, vols. i. ii.

† See map of volcanic lines which I have reduced and corrected from Von Buch's work on the Canaries.

feet high and four miles round.* Langsdorf also mentions a rock of equal height, consisting of trachyte, said to have made its appearance at once from the bottom of the sea in the year 1795.† Earthquakes of the most terrific description agitate and alter the bed of the sea and surface of the land throughout this tract. The line is continued in the southern extremity of the peninsula of Kamtschatka, where there are seven active volcanos, which, in some eruptions, have scattered ashes to immense distances. The Kurile chain of islands constitutes the prolongation of the range, where a train of volcanic mountains, nine of which are known to have been in eruption, trends in a southerly direction. In these, and in the bed of the adjoining sea, alterations of level have resulted from earthquakes since the middle of the last century. The line is then continued to the south-west in the great island of Jesso, where there are active volcanic vents, as also in Nipon, the principal of the Japanese group, where the number of burning mountains is very great; slight shocks of earthquakes being almost incessant, and violent ones experienced at distant intervals. Between the Japanese and Philippine Islands, the communication is preserved by several small insular vents. Sulphur Island, in the Loo Choo archipelago, emits sulphureous vapour; and Formosa suffers greatly from earthquakes. In Luzon, the most northern and largest of the Philippines, are three active volcanos; Mindinao also was in eruption in 1764. The line is then prolonged through Sanguir and the north-eastern extremity of Celebes, by Ternate and Tidore, to the Moluc-

* Von Hoff, vol. ii. p. 414.

† Referred to by Daubeny, Encycl. Metr. Part. 38. p. 725.

cas, and, amongst the rest, Sumbawa. Here a great transverse line may be said to run from east to west. On the west it passes through the whole of Java, where there are thirty-eight large volcanic mountains, many of which continually discharge smoke and sulphureous vapours. In the volcanos of Sumatra, the same linear arrangement is preserved; but the line inclines gradually to the north-west in such a manner as to point to the active volcano in Barren Island, in the Bay of Bengal, in about the twelfth degree of north latitude. (See Plate of volcanic band of Molucca and Sunda Islands, p. 99.) In another direction the volcanic range is prolonged through Borneo, Celebes, Banda, and New Guinea; and farther eastward in New Britain, New Ireland, and various parts of the Polynesian archipelago. The Pacific Ocean, indeed, seems, in equatorial latitudes, to be one vast theatre of igneous action; and its innumerable archipelagos, such as the New Hebrides, Friendly and Georgian Islands, are all composed either of coralline limestones, or volcanic rocks, with active vents here and there interspersed. The abundant production of carbonate of lime in solution, would alone raise a strong presumption of the volcanic constitution of these tracts, even if there were not more positive proofs of igneous agency.

Volcanic region from the Caspian to the Azores.—If we now turn our attention to the principal region in the Old World, which, from time immemorial, has been agitated by earthquakes, and has given vent, at certain points, to subterranean fires, we find that it possesses the same general characters. This region extends from east to west for the distance of about one thousand geographical miles, from the Caspian Sea to the Azores; including within its limits the greater part of

the Mediterranean, and its most prominent peninsulas. From south to north, it reaches from about the thirty-fifth to the forty-fifth degree of latitude. Its northern boundaries are Caucasus, the Black Sea, the mountains of Thrace, Transylvania, and Hungary — the Austrian, Tyrolian, and Swiss Alps — the Cevennes and Pyrenees, with the mountains which branch off from the Pyrenees westward, to the north side of the Tagus. Its western limits are the ocean, but it is impossible to determine how far it may be prolonged in that direction; neither can we assign with precision its extreme eastern limit, since the country beyond the Caspian and the Sea of Aral is little known. Capt. A. Burnes, in his recent expedition through the valley of the Oxus, found that the whole basin of that river had a few weeks before he passed through it been convulsed by a tremendous earthquake, which had thrown down buildings and obstructed the courses of rivers.

The great steppe of Tartary is unexplored; and we are almost equally ignorant of the physical constitution of China, in which country many violent earthquakes have been felt. The southern boundaries of the region include the most northern parts of Africa, and part of the Desert of Arabia.* We may trace, through the whole area comprehended within these extensive limits, numerous points of volcanic eruptions, hot springs, gaseous emanations, and other signs of igneous agency; while few tracts, of any extent, have been entirely exempt from earthquakes throughout the last three thousand years.

Borders of the Caspian.—To begin on the Asiatic side, we find that, on the western shores of the Cas-

* Von Hoff, vol. ii. p. 99.

pian, in the country round Baku, there is a tract called the Field of Fire, which continually emits inflammable gas, while springs of naphtha and petroleum occur in the same vicinity, as also mud volcanos. In the chain of Elburs, to the south of this sea, is a lofty mountain, which, according to Morier, sometimes emits smoke, and at the base of which are several small craters, where sulphur and saltpetre are procured in sufficient abundance to be used in commerce. Violent subterranean commotions have been experienced along the borders of the Caspian; and it is reported that, since 1556, the waters of that sea have encroached on the Russian territory to the north; but the fact, as Malte-Brun observes, requires confirmation. According to Engelhard and Parrot, the depth of the water has increased in places, while the general surface has been lowered; and they say that the bottom of the sea has, in modern times, varied in form; and that, near the south coast, the Isle of Idak, north from Astrabat, formerly high land, has now become very low.* Any indications of a change in the relative levels of the land in this part of Asia, are of more than ordinary interest; because a succession of similar variations would account for many prominent features in the physical geography of the district between the salt lake Aral and the western shores of the Black Sea—a district well known to have been always subject to great earthquakes.

Steppes of the Caspian.—The level of the Caspian is lower than that of the Black Sea, by about 350 feet. A low and level tract, called the Steppe, abound-

* Travels in the Crimea and Caucasus, in 1815, vol. i. pp. 257, 264.—Von Hoff, vol. i. p. 137.

ing in saline plants, and composed of tertiary strata containing many shells of species now common in the adjoining sea, skirts the north-western shores of the Caspian. This plain often terminates abruptly by a line of inland cliffs, at the base of which runs a kind of beach, consisting of fragments of limestone and sand, cemented together into a conglomerate. Pallas has endeavoured to show that there is an old line of sandy country, which indicates the ancient bed of a strait, by which the Caspian was once united to the sea of Azof. On similar grounds, it is inferred that the salt lake Aral was formerly connected with the Caspian.

Tradition of deluges on the shores of the Bosphorus, &c.—The convulsions which have produced the phenomena of the steppes may be very modern in the earth's history, and yet a small portion of them only may have happened in the last twenty or thirty centuries. Remote traditions have come down to us of inundations, in which the waters of the Euxine were forced through the Thracian Bosphorus, and through the Hellespont, into the Ægean; and in the deluge of Samothrace, it appears that that small island, and the adjoining coast of Asia, were inundated. In the Ogygian also, which happened at a different time, Bœotia and Attica were overflowed. Notwithstanding the mixture of fable, and the love of the marvellous, in those rude ages, and the subsequent inventions of Greek poets and historians, it may be distinctly perceived that the floods alluded to were local and transient, and that they happened in succession near the borders of that chain of inland seas. They may, perhaps, have been nothing more than great waves, which, about fifteen centuries before our era, devastated the

borders of the Black Sea, the Sea of Marmora, the Archipelago, and neighbouring coasts, in the same manner as the western shores of Portugal, Spain, and Northern Africa were inundated, during the great earthquake at Lisbon, by a wave which rose, in some places, to the height of fifty or sixty feet; or as happened in Peru, in 1746, where two hundred violent shocks followed each other in the space of twenty-four hours, and the ocean broke with impetuous force upon the land, destroying the town of Callao, and four other seaports, and permanently converted a considerable tract of inhabited country, which had perhaps sunk down below its former level, into a bay. Diodorus Siculus, in his account of the Samothracian deluge, informs us that the inhabitants had time to take refuge in the mountains, and save themselves by flight; he also relates that, long after the event, the fishermen of the island drew up in their nets the capitals of columns, which, he says, were the remains of cities submerged by that terrible catastrophe. * These statements scarcely leave any doubt that the event consisted of a subsidence of the coast, accompanied by a series of earthquakes, and successive inroads of the sea.

In the country between the Caspian and the Black Seas, and in the chain of Caucasus, numerous earthquakes have, in modern times, caused fissures and subsidences of the soil, especially at Tiflis.† The Caucasian territories abound in hot-springs and mineral waters. So late as 1814, a new island was raised by volcanic explosions, in the Sea of Azof; and Pallas

* Book v. chap. 46. See letter of M. Virlet, Bulletin de la Soc. Géol. de France, vol. ii. p. 341.

† Von Hoff, vol. ii. p. 210.

mentions that, in the same locality, opposite old Temruk, a submarine eruption took place in 1799, accompanied with dreadful thundering, emission of fire and smoke, and the throwing up of mire and stones. Violent earthquakes were felt at the same time at great distances from Temruk. The country around Erzerum exhibits similar phenomena, as does that around Tauris and the lake of Urmia, in which latter we have already remarked the rapid formation of travertin. The lake of Urmia, which is about 280 English miles in circumference, resembles the Dead Sea, in having no outlet, and in being more salt than the ocean. Between the Tigris and Euphrates, also, there are numerous springs of naptha, and frequent earthquakes agitate the country.

Syria and Palestine abound in volcanic appearances, and very extensive areas have been shaken, at different periods, with great destruction of cities and loss of lives. Continual mention is made in history of the ravages committed by earthquakes in Sidon, Tyre, Berytus, Laodicea, and Antioch, and in the island of Cyprus. The country around the Dead Sea appears evidently, from the accounts of modern travellers, to be volcanic. A district near Smyrna, in Asia Minor, was termed by the Greeks Catacecaumene, or the burnt, where there is a large arid territory, without trees, and with a cindery soil.*

Periodical alternation of Earthquakes in Syria and Southern Italy.—It has been remarked by Von Hoff, that from the commencement of the thirteenth to the latter half of the seventeenth century, there was an almost entire cessation of earthquakes in Syria and

* Strabo, Ed. Fal., p. 900.

Judea; and, during this interval of quiescence, the Archipelago, together with part of the adjacent coast of Lesser Asia, as also Southern Italy and Sicily, suffered greatly from earthquakes; while volcanic eruptions were unusually frequent in the same regions. A more extended comparison, also, of the history of the subterranean convulsions of these tracts seems to confirm the opinion, that a violent crisis of commotion never visits both at the same time. It is impossible for us to declare, as yet, whether this phenomenon is constant in this and other regions, because we can rarely trace back a connected series of events farther than a few centuries; but it is well known that, where numerous vents are clustered together within a small area, as in many archipelagos for instance, two of them are never in violent eruption at once. If the action of one becomes very great for a century or more, the others assume the appearance of spent volcanos. It is, therefore, not improbable that separate provinces of the same great range of volcanic fires may hold a relation to one deep-seated focus, analogous to that which the apertures of a small group bear to some more superficial rent or cavity. Thus, for example, we may conjecture that, at a comparatively small distance from the surface, Ischia and Vesuvius mutually communicate with certain fissures, and that each affords relief alternately to elastic fluids and lava there generated. So we may suppose Southern Italy and Syria to be connected, at a much greater depth, with a lower part of the very same system of fissures; in which case any obstruction occurring in one duct may have the effect of causing almost all the vapour and melted matter to be forced up the other, and if they cannot get vent, they may be the cause of violent earthquakes.

Grecian Archipelago. — Proceeding westwards, we reach the Grecian Archipelago, where Santorin, afterwards to be described, is the grand centre of volcanic action. To the north-west of Santorin is another volcano in the island of Milo, of recent aspect, having a very active solfatara in its central crater, and many sources of boiling water and steam. Continuing the same line, we arrive at that part of the Morea, where we learn, from ancient writers, that Helice and Bura were, in the year 373 B. C., submerged beneath the sea by an earthquake; and the walls, according to Ovid, were to be seen beneath the waters. Near the same spot, in our times (1817), Vostizza was laid in ruins by a subterranean convulsion.* At Methone, also (now Modon), in Messenia, about three centuries before our era, an eruption threw up a great volcanic mountain, which is represented by Strabo as being nearly four thousand feet in height; but the magnitude of the hill requires confirmation. Some suppose that the accounts of the formation of a hill near Trœzene, of which the date is unknown, may refer to the same event.

It was Von Buch's opinion that the volcanos of Greece were arranged in a line running N. N. W. and S. S. E., as represented in the map, Pl. 3.; and that they afforded the only example in Europe of active volcanos having a linear direction.† But observations made during the late French expedition to the Morea have by no means confirmed this view. On the contrary, M. Virlet announces as the result of his investigations, that there is no one determinate line of direc-

* Von Hoff, vol. ii. p. 172.

† See plate of volcanic bands, p. 99.

tion for the volcanic phenomena in Greece, whether we follow the points of eruptions, or the earthquakes, or any other signs of igneous agency.

Macedonia, Thrace, and Epirus, have always been subject to earthquakes, and the Ionian Isles are continually convulsed. Respecting Southern Italy, Sicily, and the Lipari Isles, it is unnecessary to enlarge here, as the existence of volcanos in that region is known to all, and I shall have occasion again to allude to them.

The north-eastern portion of Africa, including Egypt, which lies six or seven degrees south of the volcanic line already traced, has been almost always exempt from earthquakes; but the north-western portion, especially Fez and Morocco, which fall within the line, suffer greatly from time to time. The southern part of Spain, also, and Portugal, have generally been exposed to the same scourge simultaneously with Northern Africa. The provinces of Malaga, Murcia, and Granada, and in Portugal, the country round Lisbon, are recorded at several periods to have been devastated by great earthquakes. It will be seen, from Michell's account of the great Lisbon shock in 1755, that the first movement proceeded from the bed of the ocean ten or fifteen leagues from the coast. So late as February 2. 1816, when Lisbon was vehemently shaken, two ships felt a shock in the ocean west from Lisbon; one of them at the distance of 120, and the other 262 French leagues from the coast* — a fact which is the more interesting, because a line drawn through the Grecian archipelago, the volcanic region of Southern Italy, Sicily, Southern Spain, and Portu-

* Verneur, Journal des Voyages, vol. iv. p. 111. Von Hoff, vol. ii. p. 275.

gal, will, if prolonged westward through the ocean, strike the volcanic group of the Azores, which has, therefore, in all probability, a submarine connection with the European line. How far the island of Madeira, which has been subject to violent earthquakes, and the Canary Islands, in which volcanic eruptions have been frequent, may communicate beneath the waters with the same great region, must for the present be mere matter of conjecture.

Besides the continuous spaces of subterranean disturbance, of which we have merely sketched the outline, there are other disconnected volcanic groups, of which the geographical extent is as yet very imperfectly known. Among these may be mentioned Iceland, which belongs, perhaps, to the same region as the volcano in Jan Mayen's Island, situated 5° to the north-east. With these, also, part of the nearest coast of Greenland, which is sometimes shaken by earthquakes, may be connected.

In another hemisphere the island of Bourbon belongs to a theatre of volcanic action, of which Madagascar probably forms a part, if the alleged existence of burning volcanos in that island shall, on further examination, be substantiated. In following round the borders of the Indian Ocean to the north, we find the volcano of Gabel Tor, within the entrance of the Arabian Gulf. In the province of Cutch earthquakes are frequent, and at Mhurr, twenty-five miles from Luckput, there is an active volcano, or at least a solfatara.* In Malwa, as also in Chittagong, in Bengal, there have been violent earthquakes within the historical period.

* On the authority of Capt. A. Burnes.

Volcanic regions of Southern Europe. — Respecting the volcanic system of Southern Europe, it may be observed, that there is a central tract where the greatest earthquakes prevail, in which rocks are shattered, mountains rent, the surface elevated or depressed, and cities laid in ruins. On each side of this line of greatest commotion there are parallel bands of country, where the shocks are less violent. At a still greater distance (as in Northern Italy, for example, extending to the foot of the Alps), there are spaces where the shocks are much rarer and more feeble, yet possibly of sufficient force to cause, by continued repetition, some appreciable alteration in the external form of the earth's crust. Beyond these limits, again, all countries are liable to slight tremors at distant intervals of time, when some great crisis of subterranean movement agitates an adjoining volcanic region; but these may be considered as mere vibrations, propagated mechanically through the external covering of the globe, as sounds travel almost to indefinite distances through the air. Shocks of this kind have been felt in England, Scotland, Northern France, and Germany — particularly during the Lisbon earthquake. But these countries cannot, on this account, be supposed to constitute parts of the southern volcanic region, any more than the Shetland and Orkney Islands can be considered as belonging to the Icelandic circle, because the sands ejected from Hecla have been wafted thither by the winds.

Lines of active and extinct Volcanos not to be confounded. — We must also be careful to distinguish between lines of extinct and active volcanos, even where they appear to run in the same direction; for ancient and modern systems may cross and interfere

with each other. Already, indeed, we have proof that this is the case; so that it is not by geographical position, but by reference to the species of organic beings alone, whether aquatic or terrestrial, whose remains occur in beds interstratified with lavas, that we can clearly distinguish the relative age of volcanos of which no eruptions are recorded. Had Southern Italy been known to civilized nations for as short a period as America, we should have had no record of eruptions in Ischia; yet we might have assured ourselves that the lavas of that isle had flowed since the Mediterranean was inhabited by the species of testacea now living in the Neapolitan seas.* With this assurance it would not have been rash to include the numerous vents of that island in the modern volcanic group of Campania.

On similar grounds we may infer, without much hesitation, that the eruptions of Etna and the modern earthquakes of Calabria, are a continuation of that action, which, at a somewhat earlier period, produced the submarine lavas of the Val di Noto in Sicily.† But the lavas of the Euganean hills and the Vicentin, although not wholly beyond the range of earthquakes in Northern Italy, must not be confounded with any existing volcanic system; for when they flowed, the seas were inhabited by animals almost all of them distinct from those now known to live, whether in the Mediterranean or other parts of the globe. But an examination of these topics would carry us to events anterior to the times of history; we must therefore defer their consideration to the 4th Book.

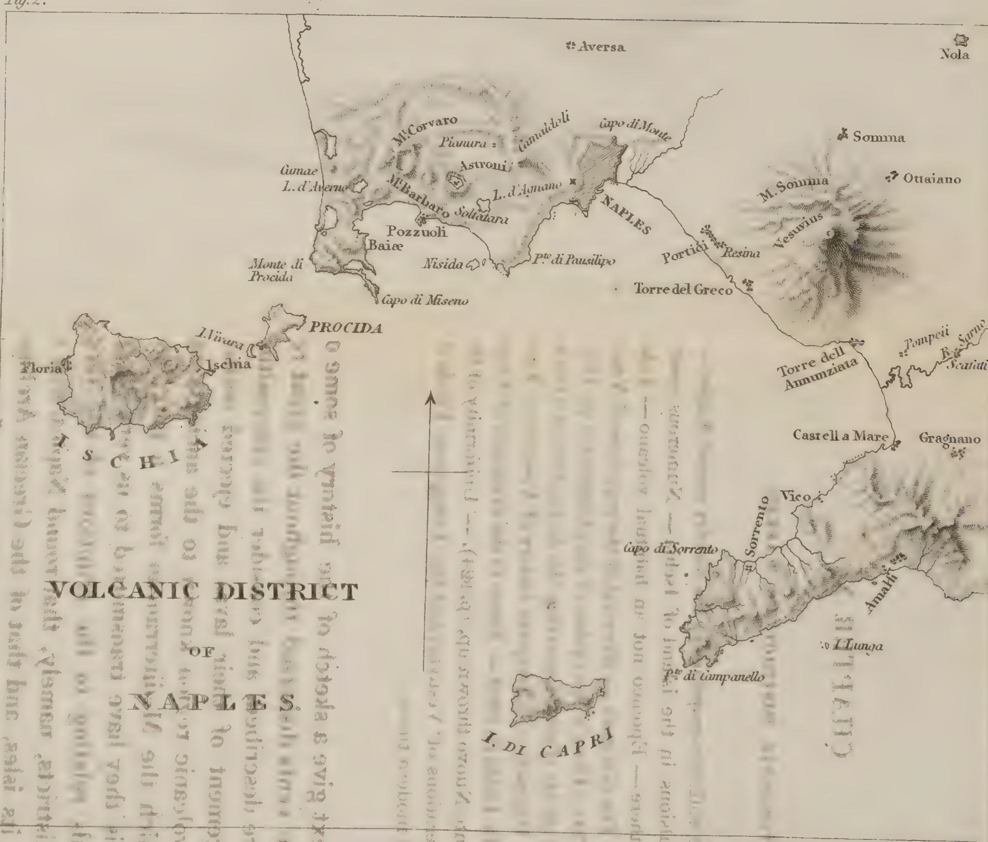
* See account of Ischia, book iv. chap. 10.

† Book iv. ch. 6.

Fig. 1

Pl. I.

Fig. 2.



CHAPTER X.

VOLCANIC DISTRICT OF NAPLES.

History of the volcanic eruptions in the district round Naples — Early convulsions in the island of Ischia — Numerous cones thrown up there — Epomeo not an habitual volcano — Lake Avernus — The Solfatara — Renewal of the eruptions of Vesuvius, A. D. 79 — Pliny's description of the phenomena, (p. 119). — Remarks on his silence respecting the destruction of Herculaneum and Pompeii — Subsequent history of Vesuvius — Lava discharged in Ischia in 1302 — Pause in the eruptions of Vesuvius — Monte Nuovo thrown up, (p. 124). — Uniformity of the volcanic operations of Vesuvius and the Phlegræan Fields in ancient and modern times.

I SHALL next give a sketch of the history of some of the volcanic vents dispersed throughout the great regions before described, and consider the composition and arrangement of their lavas and ejected matter. The only volcanic region known to the ancients was that of which the Mediterranean forms a part; and even of this they have transmitted to us very imperfect records relating to the eruptions of the three principal districts, namely, that round Naples, that of Sicily and its isles, and that of the Grecian Archipelago. By far the most connected series of records throughout a long period relates to the first of these provinces; and these cannot be too attentively considered, as much historical information is indispensable

in order to enable us to obtain a clear view of the connection and alternate mode of action of the different vents in a single volcanic group.

Early convulsions in the Island of Ischia. — The Neapolitan volcanos extend from Vesuvius, through the Phlegræan Fields, to Procida and Ischia, in a somewhat linear arrangement, ranging from the north-east to the south-west, as will be seen in the annexed map of the volcanic district of Naples, (plate 4.) Within the space above limited, the volcanic force is sometimes developed in single eruptions from a considerable number of irregularly scattered points; but a great part of its action has been confined to one principal and habitual vent, Vesuvius or Somma. Before the Christian era, from the remotest periods of which we have any tradition, this principal vent was in a state of inactivity. But terrific convulsions then took place from time to time in Ischia (Pithecusa), and seem to have extended to the neighbouring isle of Procida (Prochyta); for Strabo * mentions a story of Procida having been torn asunder from Ischia; and Pliny † derives its name from its having been poured forth by an eruption from Ischia.

The present circumference of Ischia along the water's edge is eighteen miles, its length from west to east about five, and its breadth from north to south three miles. Several Greek colonies which settled there before the Christian era were compelled to abandon it in consequence of the violence of the eruptions. First the Erythræans, and afterwards the Chalcidians, are mentioned as having been driven out by earthquakes and igneous exhalations. A colony was after-

* Lib. v. † Nat. Hist., lib. iii. c. 6.

wards established by Hiero, king of Syracuse, about 380 years before the Christian era; but when they had built a fortress, they were compelled by an eruption to fly, and never again returned. Strabo tells us that Timæus recorded a tradition, that, a little before his time, Epomeus, the principal mountain in the centre of the island, vomited fire during great earthquakes; that the land between it and the coast had ejected much fiery matter, which flowed into the sea, and that the sea receded for the distance of three stadia, and then returning, overflowed the island. This eruption is supposed by some to have been that which formed the crater of Monte Corvo on one of the higher flanks of Epomeo, above Foria, the lava-current of which may still be traced, by aid of the scoriæ on its surface, from the crater to the sea.

To one of the subsequent eruptions in the lower parts of the isle, which caused the expulsion of the first Greek colony, Monte Rotaro has been attributed, and it bears every mark of recent origin. The cone is remarkably perfect, and has a crater on its summit precisely resembling that of Monte Nuovo; but the hill is larger, and resembles some of the more considerable cones of single eruption near Clermont in Auvergne, and, like some of them, it has given vent to a lava-stream at its base, instead of its summit. A small ravine swept out by a torrent exposes the structure of the cone, which is composed of innumerable inclined and slightly undulating layers of pumice, scoriæ, white lapilli, and enormous angular blocks of trachyte. These last have evidently been thrown out by violent explosions, like those which in 1822 launched from Vesuvius a mass of pyroxenic lava, of many tons

weight, to the distance of three miles, which fell in the garden of Prince Ottajano. The cone of Rotaro is covered with the arbutus, and other beautiful evergreens. Such is the strength of the virgin soil, that the shrubs have become almost arborescent; and the growth of some of the smaller wild plants has been so vigorous, that botanists have scarcely been able to recognize the species.

The eruption which dislodged the Syracusan colony is supposed to have given rise to that mighty current which forms the promontory of Zaro and Caruso. The surface of these lavas is still very arid and bristling, and is covered with black scoriæ; so that it is not without great labour that human industry has redeemed some small spots, and converted them into vineyards. Upon the produce of these vineyards the population of the island is almost entirely supported. It amounts at present to about twenty-five thousand, and is on the increase.

From the date of the great eruption last alluded to, down to our own time, Ischia has enjoyed tranquillity, with the exception of one emission of lava hereafter to be described, which, although it occasioned much local damage, does not appear to have devastated the whole country, in the manner of more ancient explosions. There are, upon the whole, on different parts of Epomeo, or scattered through the lower tracts of Ischia, twelve considerable volcanic cones, which have been thrown up since the island was raised above the surface of the deep; and many streams of lava may have flowed, like that of 'Arso' in 1302, without cones having been produced; so that this island may, for ages before the period of the remotest traditions,

have served as a safety-valve to the whole Terra di Lavoro, while the fires of Vesuvius were dormant.*

Lake Avernus. — It seems also clear, that Avernus, a circular lake near Puzzuoli, about half a mile in diameter, which is now a salubrious and cheerful spot, once exhaled mephitic vapours, such as are often emitted by craters after eruptions. There is no reason for discrediting the account of Lucretius, that birds could not fly over it without being stifled, although they may now frequent it uninjured.† There must have been a time when this crater was in action; and for many centuries afterwards it may have deserved the appellation of "atri janua Ditis," emitting, perhaps, gases as destructive of animal life as those suffocating vapours given out by Lake Quilotoa, in Quito, in 1797, by which whole herds of cattle on its shores were killed ‡, or as those deleterious emanations which annihilated all the cattle in the island of Lancerote, one of the Canaries, in 1730.§ Bory St. Vincent mentions, that in the same isle birds fell lifeless to the ground; and Sir William Hamilton informs us that he picked up dead birds on Vesuvius during an eruption.

Solfatara. — The Solfatara, near Puzzuoli, which may be considered as a nearly extinguished crater, appears, by the accounts of Strabo and others, to have been before the Christian era in very much the same

* For an account of the geology of Ischia, see book iv. ch. 10.

† De Rerum Nat., vi. 740. — Mr. Forbes on the Bay of Naples, Edin. Journ. of Science, No. iii. new series, p. 87. Jan. 1830.

‡ Humboldt, Voy., p. 317.

§ Von Buch, Uber einen vulcanischen Ausbruch auf der Insel Lanzerote.

state as at present, giving vent continually to aqueous vapour, together with sulphureous and muriatic acid gases, like those evolved by Vesuvius.

Ancient history of Vesuvius. — Such, then, were the points where the subterranean fires obtained vent, from the earliest period to which tradition reaches back, down to the first century of the Christian era; but we then arrive at a crisis in the volcanic action of this district — one of the most interesting events witnessed by man during the brief period throughout which he has observed the physical changes on the earth's surface. From the first colonization of Southern Italy by the Greeks, Vesuvius afforded no other indications of its volcanic character than such as the naturalist might infer, from the analogy of its structure to other volcanos. These were recognized by Strabo, but Pliny did not include the mountain in his list of active vents. The ancient cone was of a very regular form, terminating, not as at present, in two peaks, but with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom. On the exterior, the flanks of the mountains were clothed with fertile fields richly cultivated, and at its base were the populous cities of Herculaneum and Pompeii. But the scene of repose was at length doomed to cease, and the volcanic fire was recalled to the main channel, which, at some former unknown period, had given passage to repeated streams of melted lava, sand, and scoriæ.

Renewal of its eruptions. — The first symptom of the revival of the energies of this volcano was the occurrence of an earthquake in the year 63 after Christ, which did considerable injury to the cities in its

vicinity. From that time to the year 79 slight shocks were frequent; and in the month of August of that year they became more numerous and violent, till they ended at length in an eruption. The elder Pliny, who commanded the Roman fleet, was then stationed at Misenum; and in his anxiety to obtain a near view of the phenomena, he lost his life, being suffocated by sulphureous vapours. His nephew, the younger Pliny, remained at Misenum, and has given us, in his Letters, a lively description of the awful scene. A dense column of vapour was first seen rising vertically from Vesuvius, and then spreading itself out laterally, so that its upper portion resembled the head, and its lower the trunk of the pine which characterizes the Italian landscape. This black cloud was pierced occasionally by flashes of fire as vivid as lightning, succeeded by darkness more profound than night. Ashes fell even upon the ships at Misenum, and caused a shoal in one part of the sea — the ground rocked, and the sea receded from the shores, so that many marine animals were seen on the dry sand. The appearances above described agree perfectly with those witnessed in more recent eruptions, especially those of Monte Nuovo in 1538, and of Vesuvius in 1822.

Silence of Pliny respecting the destruction of Herculaneum and Pompeii. — In all times and countries, indeed, there is a striking uniformity in the volcanic phenomena; but it is most singular that Pliny, although giving a circumstantial detail of so many physical facts, and describing the eruption, earthquake, and shower of ashes which fell at Stabiæ, makes no allusion to the sudden overwhelming of two large and populous cities, Herculaneum and Pompeii. All naturalists who have searched into the memorials of the past for records

of physical events, must have been surprised at the indifference with which the most memorable occurrences are often passed by, in the works of writers of enlightened periods; as also of the extraordinary exaggeration which usually displays itself in the traditions of similar events, in ignorant and superstitious ages. But no omission is more remarkable than that now under consideration: nor has the circumstance, we think, been at all explained by the suggestion that the chief object of the younger Pliny was to give Tacitus a full account of the particulars of his uncle's death. We have no hesitation in saying, that had the buried cities never been discovered, the accounts transmitted to us of their tragical end would have been discredited by the majority, so vague and general are the narratives, or so long subsequent to the event. Tacitus, the friend and contemporary of Pliny, when adverting in general terms to the convulsions, says merely that "cities were consumed or buried."*

Suetonius, although he alludes to the eruption incidentally, is silent as to the cities. They are mentioned by Martial, in an epigram, as immersed in cinders; but the first historian who alludes to them by name is Dion Cassius†, who flourished about a century and a half after Pliny. He appears to have derived his information from the traditions of the inhabitants, and to have recorded, without discrimination, all the facts and fables which he could collect. He tells us, "that during the eruption a multitude of men of superhuman stature, resembling giants, appeared, sometimes on the mountain, and sometimes in

* Haustæ aut obrutæ urbes. — Hist., lib. i.

† Hist. Rom., lib. lxvi.

the environs—that stones and smoke were thrown out, the sun was hidden, and then the giants seemed to rise again, while the sounds of trumpets were heard, &c. &c.: and finally," he relates, "two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, while all the people were sitting in the theatre." That many of these circumstances were invented would have been obvious, even without the aid of Pliny's letters; and the examination of Herculaneum and Pompeii enables us to prove, that none of the people were destroyed in the theatres, and, indeed, that there were very few of the inhabitants who did not escape from both cities. Yet some lives were lost, and there was ample foundation for the tale in its most essential particulars.

This case may often serve as a caution to the geologist, who has frequent occasion to weigh, in like manner, negative evidence derived from the silence of eminent writers, against the obscure but positive testimony of popular traditions. Some authors, for example, would have us call in question the reality of the Ogygian deluge, because Homer and Hesiod say nothing of it. But they were poets, not historians, and they lived many centuries after the latest date assigned to the catastrophe. Had they even lived at the time of that flood, we might still contend that their silence ought, no more than Pliny's, to avail against the authority of tradition, however much exaggeration we may impute to the traditional narrative of the event.

It does not appear that in the year 79 any lava flowed from Vesuvius; the ejected substances, perhaps, consisted entirely of lapilli, sand, and fragments of older lava, as when Monte Nuovo was thrown up in

1538. The first era at which we have authentic accounts of the flowing of a stream of lava, is the year 1036, which is the seventh eruption from the revival of the fires of the volcano. A few years afterwards, in 1049, another eruption is mentioned, and another in 1138 (or 1139), after which a great pause ensued of 168 years. During this long interval of repose, two minor vents opened at distant points. First, it is on tradition that an eruption took place from the Solfatara in the year 1198, during the reign of Frederic II., Emperor of Germany; and although no circumstantial detail of the event has reached us from those dark ages, we may receive the fact without hesitation.* Nothing more, however, can be attributed to this eruption, as Mr. Scrope observes, than the discharge of a light and scoriform trachytic lava, of recent aspect, resting upon the strata of loose tuff which covers the principal mass of trachyte.†

Volcanic eruption in Ischia, 1302. — The other occurrence is well authenticated, — the eruption, in the year 1302, of a lava-stream from a new vent on the south-east side of the Island of Ischia. During part of 1301, earthquakes had succeeded one another with fearful rapidity; and they terminated at last with the discharge of a lava-stream from a point named the Campo del Arso, not far from the town of Ischia. This lava ran quite down to the sea — a distance of about two miles; in colour it varies from iron grey to reddish black, and is remarkable for the glassy felspar

* The earliest authority, says Mr. Forbes, given for this fact, appears to be Capaccio, quoted in the Terra Tremante of Bonito. — Edin. Journ. of Sci. &c. No. I., new series, p. 127. July, 1829.

† Geol. Trans., vol. ii. part iii. p. 346. second series.

which it contains. Its surface is almost as sterile, after a period of five centuries, as if it had cooled down yesterday. A few scantlings of wild thyme, and two or three other dwarfish plants, alone appear in the interstices of the scoriæ, while the Vesuvian lava of 1767 is already covered with a luxuriant vegetation. Pontanus, whose country-house was burnt and overwhelmed, describes the dreadful scene as having lasted two months.* Many houses were swallowed up, and a partial emigration of the inhabitants followed. This eruption produced no cone, but only a slight depression, hardly deserving the name of a crater, where heaps of black and red scoriæ lie scattered around. Until this eruption, Ischia is generally believed to have enjoyed an interval of rest for about seventeen centuries; but Julius Obsequens†, who flourished A.D. 214, refers to some volcanic convulsions in the years 662 after the building of Rome (91 B.C.). As Pliny, who lived a century before Obsequens, does not enumerate this among other volcanic eruptions, the statement of the latter author is supposed to have been erroneous; but it would be more consistent, for reasons before stated, to disregard the silence of Pliny, and to conclude that some kind of subterranean commotion, probably of no great violence, happened at the period alluded to.

History of Vesuvius after 1138.—To return to Vesuvius:—the next eruption occurred in 1306; between which era and 1631 there was only one other (in 1500), and that a slight one. It has been remarked, that throughout this period Etna was in a

* Lib. vi. de Bello Neap. in Grævii Thesaur.

† Prodig. libell., c. cxiv.

state of such unusual activity as to lend countenance to the idea that the great Sicilian volcano may sometimes serve as a channel of discharge to elastic fluids and lava that would otherwise rise to the vents in Campania.

Formation of Monte Nuovo, 1538.—The great pause was also marked by a memorable event in the Phlegræan Fields — the sudden formation of a new mountain in 1538, of which we have received authentic accounts from contemporary writers. Frequent earthquakes, for two years preceding, disturbed the neighbourhood of Puzzuoli; but it was not until the 27th and 28th of September, 1538, that they became alarming, when not less than twenty shocks were experienced in twenty-four hours. At length, on the night of the 29th, two hours after sunset, a gulf opened between the little town of Tripergola, which once existed on the site of the Monte Nuovo, and the baths in its suburbs, which were much frequented. This watering-place contained an hospital for those who resorted thither for the benefit of the thermal springs, and it appears that there were no fewer than three inns in the principal street. A large fissure approached the town with a tremendous noise, and with the emission of flame; and began to discharge pumice-stones, blocks of unmelted lava, and ashes mixed with water. The ashes, by which the town was entirely overwhelmed, fell in immense quantities, even at Naples; while the neighbouring Puzzuoli was deserted by its inhabitants. The sea retired suddenly for two hundred yards, and a portion of its bed was left dry. The whole coast, from Monte Nuovo to beyond Puzzuoli, was at that time upraised to the height of many feet above the bed of the Mediterranean, and has ever since

remained permanently elevated. The proofs of this remarkable event will be considered at length when the phenomena of the Temple of Serapis are described.* On the 3d of October the eruption ceased, so that the hill (1. fig. 18.), the great mass of which was thrown up in a day and a night, was accessible; and those who ascended reported that they found a funnel-shaped crater on its summit. (2. fig. 18.)

The height of Monte Nuovo has recently been determined, by the Italian mineralogist Pini, to be 440 English feet above the level of the bay; its base is about eight thousand feet, or nearly a mile and a half, in circumference. According to Pini, the depth of the crater is 421 English feet from the summit of the hill,

Fig. 18.

Monte Nuovo, formed in the Bay of Baiæ, Sept. 29th, 1538.

1. Cone of Monte Nuovo. 2. Brim of crater of ditto.
3. Thermal spring, called Baths of Nero, or Stufe di Tritoli.

* See chap. xvi.

so that its bottom is only nineteen feet above the level of the sea. No lava flowed from this cavity, but the ejected matter consisted of pumiceous scoriæ and masses of trachyte, many of them schistose, and resembling clinkstone. The Monte Nuovo is declared, by the best authorities, to stand partly on the site of the Lucrine Lake (4. fig. 19.*), which was nothing more than the crater of a pre-existent volcano, and was almost entirely filled during the explosion of 1538. Nothing now remains but a shallow pool, separated from the sea by an elevated beach, raised artificially.

Fig. 19.

The Phlegræan Fields.

1. Monte Nuovo. 2. Monte Barbaro.
3. Lake Avernus. 4. Lucrine Lake.
5. The Solfatara. 6. Puzzuoli.
7. Bay of Baiæ.

* This representation of the Phlegræan Fields is reduced from part of Plate xxxi. of Sir William Hamilton's great work, "Campi Phlegræi." The faithfulness of his coloured delineations of the scenery of that country cannot be too highly praised.

Volcanos of the Phlegræan Fields. — Immediately adjoining Monte Nuovo is the larger volcanic cone of Monte Barbaro (2. fig. 19.), the Gaurus inanis of Juvenal — an appellation given to it probably from its deep circular crater, which is about a mile in diameter. Large as is this cone, it was probably produced by a single eruption; and it does not, perhaps, exceed in magnitude some of the largest of those formed in Ischia, within the historical era. It is composed chiefly of indurated tufa, like Monte Nuovo, stratified conformably to its conical surface. This hill was once very celebrated for its wines, and is still covered with vineyards; but when the vine is not in leaf it has a sterile appearance, and, late in the year, when seen from the beautiful bay of Baiæ, it often contrasts so strongly in verdure with Monte Nuovo, which is always clothed with arbutus, myrtle, and other wild evergreens, that a stranger might well imagine the cone of older date to be that thrown up in the sixteenth century.*

There is nothing, indeed, so calculated to instruct the geologist as the striking manner in which the recent volcanic hills of Ischia, and that now under consideration, blend with the surrounding landscape. Nothing seems wanting or redundant; every part of the picture is in such perfect harmony with the rest, that the whole has the appearance of having been called into existence by a single effort of creative power. Yet what other result could we have anticipated, if Nature has ever been governed by the same

* Hamilton (writing in 1770) says, "The new mountain produces as yet but a very slender vegetation." — Campi Phlegræi, p. 69. This remark was no longer applicable when I saw it, in 1828.

laws? Each new mountain thrown up — each new tract of land raised or depressed by earthquakes — should be in perfect accordance with those previously formed, if the entire configuration of the surface has been due to a long series of similar disturbances. Were it true that the greater part of the dry land originated simultaneously in its present state, at some era of paroxysmal convulsion, and that additions were afterwards made slowly and successively during a period of comparative repose; then, indeed, there might be reason to expect a strong line of demarcation between the signs of ancient and modern changes. But the very continuity of the plan, and the perfect identity of the causes, are to many a source of deception; since, by producing a unity of effect, they lead them to exaggerate the energy of the agents which operated in the earlier ages. In the absence of all historical information, they are as unable to separate the dates of the origin of different portions of our continents, as the stranger is to determine, by their physical features alone, the distinct ages of Monte Nuovo, Monte Barbaro, Astroni, and the Solfatara.

The vast scale and violence of the volcanic operations in Campania, in the olden time, has been a theme of declamation, and has been contrasted with the comparative state of quiescence of this delightful region in the modern era. Instead of inferring, from analogy, that the ancient Vesuvius was always at rest when the craters of the Phlegræan Fields were burning, — that each cone rose in succession, — and that many years, and often centuries, of repose intervened between different eruptions, — geologists seem to have generally conjectured that the whole group sprung up from the ground at once, like the soldiers of Cadmus when he

sowed the dragon's teeth. As well might they endeavour to persuade us that on these Phlegræan Fields, as the poets feigned, the giants warred with Jove, ere yet the puny race of mortals were in being.

Modern Eruptions of Vesuvius. — For nearly a century after the birth of Monte Nuovo, Vesuvius continued in a state of tranquillity. There had then been no violent eruption for 492 years; and it appears that the crater was then exactly in the condition of the present extinct volcano of Astroni, near Naples. Bracini, who visited Vesuvius not long before the eruption of 1631, gives the following interesting description of the interior:—"The crater was five miles in circumference, and about a thousand paces deep; its sides were covered with brushwood, and at the bottom there was a plain on which cattle grazed. In the woody parts wild boars frequently harboured. In one part of the plain, covered with ashes, were three small pools, one filled with hot and bitter water, another salter than the sea, and a third hot, but tasteless."* But at length these forests and grassy plains were consumed, being suddenly blown into the air, and their ashes scattered to the winds. In December, 1631, seven streams of lava poured at once from the crater, and overflowed several villages on the flanks and at the foot of the mountain. Resina, partly built over the ancient site of Herculaneum, was consumed by the fiery torrent. Great floods of mud were as destructive as the lava itself, — no uncommon occurrence during these catastrophes; for such is the violence of rains produced by the evolution of aqueous

* Hamilton's Campi Phlegræi, folio, vol. i. p. 62.; and Brieslak, Campanie, tome i. p. 186.

vapour, that torrents of water descend the cone, and, becoming charged with impalpable volcanic dust, and rolling along loose ashes, acquire sufficient consistency to deserve their ordinary appellation of "aqueous lavas."

A brief period of repose ensued, which lasted only until the year 1666, from which time to the present there has been a constant series of eruptions, with rarely an interval of rest exceeding ten years. During these three centuries no irregular volcanic agency has convulsed other points in this district. Brieslak remarked, that such irregular convulsions had occurred in the Bay of Naples in every second century; as, for example, the eruption of the Solfatara in the twelfth, of the lava of Arso, in Ischia, in the fourteenth, and of Monte Nuovo in the sixteenth: but the eighteenth has formed an exception to this rule, and this seems accounted for by the unprecedented number of eruptions of Vesuvius during that period; whereas, when the new vents opened, there had always been, as we have seen, a long intermittance of activity in the principal volcano.

CHAPTER XI.

VOLCANIC DISTRICT OF NAPLES—*continued.*

Volcanic District of Naples, *continued* — Dimensions and structure of the cone of Vesuvius — Dikes in the recent cone (p. 137.) — Section through Vesuvius and Somma — Vesuvian lavas and minerals (p. 141.) — Effects of decomposition of lavas — Alluviums called "aqueous lavas" — Origin and composition of the matter enveloping Herculaneum and Pompeii — Controversies on the subject — Condition and contents of the buried cities (p. 152.) — Small number of Skeletons — State of preservation of animal and vegetable substances — Rolls of Papyrus — Probability of future discoveries of MSS. — Stabiæ (p. 158.) — Torre del Greco — Concluding remarks on the Campanian volcanos.

Structure of the cone of Vesuvius.— Between the end of the eighteenth century and the year 1822, the great crater of Vesuvius has been gradually filled by lava boiling up from below, and by scoriæ falling from the explosions of minor mouths which were formed at intervals on its bottom and sides. In place of a regular cavity, therefore, there was a rough and rocky plain, covered with blocks of lava and scoriæ, and cut by numerous fissures, from which clouds of vapour were evolved. But this state of things was totally changed by the eruption of October, 1822, when violent explosions, during the space of more than twenty days, broke up and threw out all this accumulated mass, so as to leave an immense gulf or chasm, of an irregular,

but somewhat elliptical shape, about three miles in circumference when measured along the very sinuous and irregular line of its extreme margin, but somewhat less than three quarters of a mile in its longest diameter, which was directed from N. E. to S. W.* The depth of this tremendous abyss has been variously estimated; for from the hour of its formation it decreased daily by the dilapidation of its sides. It measured, at first, according to the account of some authors, two thousand feet in depth from the extreme part of the existing summit †; but Mr. Scrope, when he saw it, soon after the eruption, estimated its depth at less than half that quantity. More than eight hundred feet of the cone was carried away by the explosions, so that the mountain was reduced in height from about 4200 to 3400 feet. ‡

As we ascend the sloping sides, the volcano appears a mass of loose materials — a mere heap of rubbish, thrown together without the slightest order; but on arriving at the brim of the crater, and obtaining a view of the interior, we are agreeably surprised to discover that the conformation of the whole displays in every part the most perfect symmetry and arrangement. The materials are disposed in regular strata, slightly undulating, appearing, when viewed in front, to be disposed in horizontal planes. But, as we make the circuit of the edge of the crater, and observe the cliffs by which it is encircled projecting or receding in salient or retiring angles, we behold transverse sections

* Account of the Eruption of Vesuvius in October, 1822, by G. P. Scrope, Esq., Journ. of Sci., &c. vol. xv. p. 175.

† Mr. Forbes, Account of Mount Vesuvius, Edin. Journ. of Sci., No. xviii. p. 195. Oct. 1828.

‡ Ibid., p. 194.

of the currents of lava and beds of sand and scoriæ, and recognize their true dip. We then discover that they incline outwards from the axis of the cone, at angles varying from 30° to 45°. The whole cone, in fact, is composed of a number of concentric coatings of alternating lavas, sand, and scoriæ. Every shower of ashes which has fallen from above, and every stream of lava descending from the lips of the crater, have conformed to the outward surface of the hill, so that one conical envelope may be said to have been sucessively folded round another, until the aggregation of the whole mountain was completed. The marked separation into distinct beds results from the different colours and degrees of coarseness in the sands, scoriæ, and lava, and the alternation of these with each other. The greatest difficulty, on the first view, is to conceive how so much regularity can be produced, notwithstanding the unequal distribution of sand and scoriæ, driven by prevailing winds in particular eruptions, and the small breadth of each sheet of lava as it first flows out from the crater.

But on a closer examination, we find that the appearance of extreme uniformity is delusive, for when a number of beds thin out gradually, and at different points, the eye does not without difficulty recognize the termination of any one stratum, but usually supposes it continuous with some other, which at a short distance may lie precisely in the same plane. The slight undulations, moreover, produced by inequalities on the sides of the hill on which the successive layers were moulded, assist the deception. As countless beds of sand and scoriæ constitute the greater part of the whole mass, these may sometimes mantle continuously round the whole cone; and even lava-streams

may be of considerable breadth when first they overflow, and, since in some eruptions a considerable part of the upper portion of the cone breaks down at once, may form a sheet extending as far as the space which the eye usually takes in in a single section.

The high inclination of some of the beds, and the firm union of the particles even where there is evidently no cement, is another striking feature in the volcanic tuffs and breccias, which seems at first not very easy of explanation. But the last great eruption afforded ample illustration of the manner in which these strata are formed. Fragments of lava, scoriæ, pumice, and sand, when they fall at slight distances from the summit, are only half cooled down from a state of fusion, and are afterwards acted upon by the heat from within, and by fumeroles or small crevices in the cone through which hot vapours are disengaged. Thus heated, the ejected fragments cohere together strongly; and the whole mass acquires such consistency in a few days, that fragments cannot be detached without a smart blow of the hammer. At the same time sand and scoriæ, ejected to a greater distance, remain incoherent.*

Sir William Hamilton, in his description of the eruption of 1779, says, that jets of liquid lava, mixed with stones and scoriæ, were thrown up to the height of at least ten thousand feet, having the appearance of a column of fire.† Some of these were directed by the winds towards Ottaiano, and some of them, falling almost perpendicularly, still red-hot and liquid, on Vesuvius, covered its whole cone, part of

* Monticelli and Covelli, Storia di Fenon. del Vesuv., en 1821-2-3.

† Campi Phlegræi.

the mountain of Somma, and the valley between them. The falling matter being nearly as vividly inflamed as that which was continually issuing fresh from the crater, formed with it one complete body of fire, which could not be less than two miles and a half in breadth, and of the extraordinary height above mentioned, casting a heat to the distance of at least six miles around it. Dr. Clarke, also, in his account of the eruption of 1793, says that millions of red-hot stones were shot into the air full half the height of the cone itself, and then bending, fell all round in a fine arch. On another occasion he says that, as they fell, they covered nearly half the cone with fire.

The same author has also described the different appearance of the lava at its source, and at some distance from it, when it had descended into the plains below. At the point where it issued, in 1793, from an arched chasm in the side of the mountain, the vivid torrent rushed with the velocity of a flood. It was in perfect fusion, unattended with any scoriæ on its surface, or any gross materials not in a state of complete solution. It flowed with the translucency of honey, "in regular channels, cut finer than art can imitate, and glowing with all the splendour of the sun." — "Sir William Hamilton," he continues, "had conceived that no stones thrown upon a current of lava would make any impression. I was soon convinced of the contrary. Light bodies, indeed, of five, ten, and fifteen pounds weight made little or no impression even at the source; but bodies of sixty, seventy, and eighty pounds were seen to form a kind of bed on the surface of the lava, and float away with it. A stone of three hundred weight, that had been thrown out by the crater, lay near the source of the

current of lava: I raised it upon one end, and then let it fall in upon the liquid lava; when it gradually sunk beneath the surface, and disappeared. If I wished to describe the manner in which it acted upon the lava, I should say that it was like a loaf of bread thrown into a bowl of very thick honey, which gradually involves itself in the heavy liquid, and then slowly sinks to the bottom.

"The lava, at a small distance from its source, acquires a darker tint upon its surface, is less easily acted upon, and, as the stream widens, the surface, having lost its state of perfect solution, grows harder and harder, and cracks into innumerable fragments of very porous matter, to which they give the name of scoriæ, and the appearance of which has led many to suppose that it proceeded thus from the mountain. There is, however, no truth in this. All lava, at its first exit from its native volcano, flows out in a liquid state, and all equally in fusion. The appearance of the scoriæ is to be attributed only to the action of the external air, and not to any difference in the materials which compose it, since any lava whatever, separated from its channel, and exposed to the action of the external air, immediately cracks, becomes porous, and alters its form. As we proceeded downward, this became more and more evident; and the same lava which at its original source flowed in perfect solution, undivided, and free from encumbrances of any kind, a little farther down had its surface loaded with scoriæ in such a manner, that, upon its arrival at the bottom of the mountain, the whole current resembled nothing so much as a heap of unconnected cinders from an iron-foundry." In another place he says, that "the rivers of lava in the plain resembled a vast heap of cinders, or the scoriæ of an iron-foundry, rolling

slowly along, and falling with a rattling noise over one another."*

It appears that the intensity of the light and heat of the lava varies considerably at different periods of the same eruption, as in that of Vesuvius in 1819 and 1820, when Sir H. Davy remarked different degrees of vividness in the white heat at the point where the lava originated.†

When the expressions "flame" and "smoke" are used in describing volcanic appearances, they must generally be understood in a figurative sense. The clouds of apparent smoke consist usually of aqueous and other vapours, or of that impalpable dust which is formed of finely comminuted volcanic scoriæ. The columns of flame are very rarely if ever derived from inflammable gases, but consist of showers of incandescent or red-hot fragments of lava, illuminated by that vivid light which is emitted from the crater below, where the lava is said to glow with the splendour of the sun.

Dikes in the recent cone, how formed.—The inclined strata before mentioned, which dip outwards in all directions from the axis of the cone of Vesuvius, are intersected by veins or dikes of compact lava, for the most part in a vertical position.‡ In 1828 these were seen to be about seven in number, some of them not less than four or five hundred feet in height, and thinning out before they reached the uppermost part of the cone. Being harder than the beds through which they pass, they have decomposed less rapidly, and therefore stand out in relief. §

* Otter's Life of Dr. Clarke.

† Phil. Trans., 1828, p. 241.

‡ See Book 4. chap. 10.

§ When I visited Vesuvius, in Nov. 1828, I was prevented from descending into the crater by the constant ejections then

There can be no doubt that these dikes have been produced by the filling up of open fissures with liquid lava; but of the date of their formation we know nothing further than that they are all subsequent to the year 79, and, relatively speaking, that they are more modern than all the lavas and scoriæ which they intersect. A considerable number of the upper strata, not traversed by them, must have been due to later eruptions, if the dikes were filled from below, and if lava rose in them to the surface. That the earthquakes, which almost invariably precede eruptions, occasion rents in the mass is well known; and, in 1822, three months before the lava flowed out, open fissures, evolving hot vapours, were numerous. It is clear that such rents must be injected with melted matter when the column of lava rises, so that the origin of the dikes is easily explained, as also the great solidity and crystalline nature of the rock composing them, which has been formed by lava cooling slowly under great pressure.

Section through Vesuvius and Somma. — In the annexed diagram (Fig. 20.) it will be seen that, on the side of Vesuvius opposite to that where a portion of

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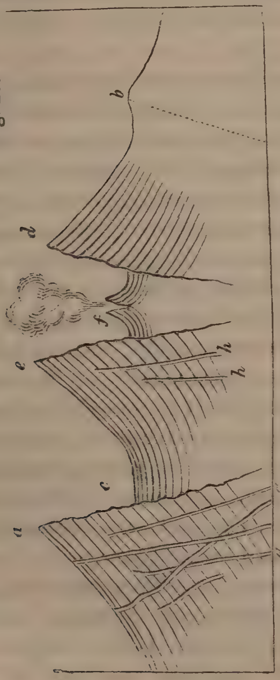
thrown out. I only got sight of three of the dikes; but Signor Monticelli had previously had drawings made of the whole, which he showed me. The veins which I saw were on that side of the cone which is encircled by Somma. In March of the year before mentioned, an eruption began at the bottom of the deep gulf formed in 1822. The ejected matter had filled up nearly one third of the original abyss in November, and the same operation was still in progress, a single black cone being seen at the bottom in almost continual activity. I found the lava of 1822 not yet cool on the north side of the cone, and evolving much heat and vapour from crevices. It was then upwards of six years since it flowed out.

the ancient cone of Somma (*a*) still remains, is a projection (*b*) called the Pedamentina, which some have supposed to be part of the circumference of the ancient crater broken down towards the sea, and over the edge of which the lavas of the modern Vesuvius have poured; the axis of the present cone of Vesuvius being, according to Visconti, precisely equidistant from the escarpment of Somma and the Pedamentina. But it has been objected (and not without reason) to this hypothesis, that, if the Pedamentina and the escarp-

Fig. 20.



Supposed section of Vesuvius and Somma.

a. Monte Somma, or the remains of the ancient cone of Vesuvius.
b. The Pedamentina, a terrace-like projection, encircling the base of the recent cone of Vesuvius, on the south side.
c. Atrio del Cavallo.*
d, e. Crater left by eruption of 1822.
f. Small cone thrown up in 1828, at the bottom of the great crater.
g, g. Dikes intersecting Somma.
h, h. Dikes intersecting the recent cone of Vesuvius.

* So called from travellers leaving their horses and mules there when they prepare to ascend the cone on foot.

ment of Somma were the remains of the original *crater*, that crater must have been many miles in diameter, and more enormous than almost any one known on the globe. It is therefore more probable that the ancient mountain was higher than Vesuvius (which, comparatively speaking, is a volcano of no great height), and that the explosions of the year 79 caused it not merely to disgorge the contents of its crater, which had long been choked up, but blew up a great part of the cone itself: so that the wall of Somma, and the ridge or terrace of the Pedamentina, were never the margin of a crater of eruption, but are the relics of a ruined and truncated cone.

It will be seen in the diagram that the slanting beds of the cone of Vesuvius become horizontal in the Atrio del Cavallo (at *c*), where the base of the new cone meets the precipitous escarpment of Somma; for when the lava flows down to this point, as happened in 1822, its desending course is arrested, and it then runs in another direction along this small valley, circling round the base of the cone. Sand and scoriæ, also, blown by the winds, collect at the base of the cone, and are then swept away by torrents; so that there is always here a flattish plain, as represented. In the same manner the small interior cone (*f*) must be composed of sloping beds, terminating in a horizontal plain; for, while this monticule was gradually gaining height by successive ejections of lava and scoriæ, in 1828, it was always surrounded by a flat pool of semi-fluid lava, into which scoriæ and sand were thrown.

The escarpment of Somma exhibits a structure precisely similar to that of the cone of Vesuvius, but the beds are intersected by a much greater number of dikes. The formation of this older cone does not be-

long to the historical era, and must not, therefore, be enlarged upon in this place; but I shall have occasion presently to revert to the subject, when speaking of a favourite doctrine of some modern geologists, concerning "craters of elevation" (Erhebungs Crater), whereby, in defiance of analogy, the origin of the identical disposition of the strata and dikes in Vesuvius and Somma has been referred to a mode of operation extremely dissimilar.

Vesuvian Lavas. — The modern lavas of Vesuvius are characterized by a large proportion of augite (or pyroxene.) When they are composed of this mineral and felspar, they may be said to differ in no way in composition from many of the ancient volcanic rocks of Scotland. They are often porphyritic, containing disseminated crystals of augite, leucite, or some other mineral, imbedded in a more earthy base. These porphyritic lavas are often extremely compact, especially in the dikes of Vesuvius and Somma, which, in hardness and specific gravity, are by no means inferior to ordinary veins of trap, and, like them, often preserve a remarkable parallelism in their two opposite faces for considerable distances.*

In regard to the structure of the Vesuvian lavas on a great scale, there are no natural sections of sufficient depth to enable us to draw fair comparisons between them and the products of extinct volcanos. At the fortress near Torre del Greco a section is exposed, fifteen feet in height, of a current which ran into the sea; and it evinces, especially in the lower part, a decided tendency to divide into rude columns. A still more striking example may be seen to the west of Torre

* See Book 4. chap. 10.

del Annunziata, near Forte Scassato, where the mass is laid open by the sea to the depth of twenty feet. In both these cases, however, the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava-currents of Central France (those of the Vivarais, in particular), the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava irregularly prismatic; and under this, there is a foundation of regular and vertical columns, but these lavas are often one hundred feet or more in thickness. We can scarcely expect to discover the same phenomenon in the shallow currents of Vesuvius, where the lowest part has cooled more rapidly, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume.

Mr. Scrope mentions that, in the cliffs encircling the modern crater of Vesuvius, he saw many currents offering a columnar division, and some almost as regularly prismatic as any ranges of the older basalts; and he adds, that in some the spheroidal concretionary structure, on a large scale, was equally conspicuous.* Brieslak † also informs us that, in the siliceous lava of 1737, which contains augite, leucite, and crystals of felspar, he found very regular prisms in a quarry near Torre del Greco; an observation confirmed by modern authorities.‡

Effects of decomposition on lavas. — The decomposition of some of the felspathic lavas, either by simple

* Journ. of Sci., vol. xv. p. 177.

† Voy. dans la Campanie, tome i. p. 201.

‡ Mr. Forbes on Mount Vesuvius, Edin. Journ. of Sci., No. xviii., Oct. 1828.

weathering, or by gaseous emanations, converts them from a hard to a soft clayey state, so that they no longer retain the smallest resemblance to rocks cooled down from a state of fusion. The exhalations of sulphuretted hydrogen and muriatic acid, which are disengaged continually from the Solfatara, also produce curious changes on the trachyte of that nearly extinct volcano: the rock is bleached and becomes porous, fissile, and honeycombed, till at length it crumbles into a white siliceous powder.* Numerous globular concretions, composed of concentric laminæ, are also formed by the same vapours in this decomposed rock.†

They who have visited the Phlegræan Fields and the volcanic regions of Sicily, and who are aware of the many problematical appearances which igneous rocks of the most modern origin assume, especially after decomposition, cannot but be astonished at the confidence with which the contending Neptunists and Vulcanists in the last century dogmatized on the origin of certain rocks of remote antiquity. Instead of having laboured to acquire an accurate acquaintance with the aspect of known volcanic rocks, and the transmutations which they undergo subsequently to their first consolidation, the adherents of both parties seem either to have considered themselves born with an intuitive knowledge of the effects of volcanic operations, or to have assumed that they required no other analogies than those which a laboratory or furnace might supply.

Vesuvian Minerals. — A great variety of minerals

* Daubeny on Volcanos, p. 169.

† Scrope, Geol. Trans., second series, vol. ii. p. 346.

are found in the lavas of Vesuvius and Somma; for so many are common to both, that it is unnecessary to separate them. Augite, leucite, felspar, mica, olivine, and sulphur, are most abundant. It is an extraordinary fact, that, in an area of three square miles round Vesuvius, a greater number of simple minerals have been found than in any spot of the same dimensions on the surface of the globe. Häuy enumerated only 380 species of simple minerals as known to him; and no less than eighty-two had been found on Vesuvius before the end of the year 1828.* Many of these are peculiar to that locality. Some mineralogists have conjectured that the greater part of these were not of Vesuvian origin, but thrown up in fragments from some older formation, through which the gaseous explosions burst. But none of the older rocks in Italy, or elsewhere, contain such an assemblage of mineral products; and the hypothesis seems to have been prompted by a disinclination to admit that, in times so recent in the earth's history, the laboratory of Nature could have been so prolific in the creation of new and rare compounds. Had Vesuvius been a volcano of high antiquity, formed when Nature

> Wanton'd as in her prime, and played at will
> Her virgin fancies,

it would have been readily admitted that these, or a much greater variety of substances, had been sublimed in the crevices of lava, just as several new earthy and metallic compounds are known to have been produced by fumeroles, since the eruption of 1822. But a violent hypothesis appears to have been resorted to,

* Monticelli and Covelli, Prodom. della Mineral. Vesuv.

in order to explain away facts which would imply the unimpaired energy of reproductive causes in our own times.

Formation of Tuffs. — The above remarks apply simply to the structure of the cone; but a small part only of the ejected matter remains so near to the volcanic orifice. A large portion of sand and scoriæ is borne by the winds and scattered over the surrounding plains: part falls into the sea; and still more is swept down by torrents into the deep, during the intervals, often protracted for many centuries, between eruptions. In this case horizontal deposits of tufaceous matter become intermixed with other kinds of sediment, and with shells and corals, so that rocks of a mixed character are formed, such as tuffs, peperinos, and volcanic conglomerates.

Flowing of lava under water. — Some of the lavas, also, of Vesuvius reach the sea, as do those of almost all volcanos; since they are generally in islands, or bordering the coast. Here they find a bottom, often levelled by operations analogous to those which form deltas; so that instead of being highly inclined, as around the cone, or in narrow bands, as in a valley, they may spread out in broad horizontal sheets. It is not improbable, as Dr. Daubeny has suggested, that they retain their fluidity for a considerable time longer beneath the sea than in the open air; for the rapidity with which heated bodies are cooled by being plunged into water arises chiefly from the conversion of the lower portions of water into steam, which steam absorbing much heat immediately ascends, and is reconverted into water. But under the pressure of an ocean sufficiently deep to prevent the formation of steam, the heat of the lava would be carried off more slowly, and

only by the circulation of ascending and descending currents of water, those portions nearest the source of heat becoming specifically lighter, and consequently displacing the water above. This kind of circulation would take place with much less rapidity than in the atmosphere, inasmuch as the expansion of water by equal increments of heat is less considerable than that of air.*

Volcanic alluviums.—In addition to the ejections which fall on the cone, and that much greater mass which finds its way gradually to the neighbouring sea, there is a third portion, often of no inconsiderable thickness, composed of alluviums, spread over the valleys and plains at small distances from the volcano. Aqueous vapours are evolved copiously from a crater during eruptions, and often for a long time subsequently to the discharge of scoriæ and lava: these vapours are condensed in the cold atmosphere surrounding the high volcanic peak, and heavy rains are thus caused in countries where, at the same season and under ordinary circumstances, such a phenomenon is entirely unknown. The floods thus occasioned sweep along the impalpable dust and light scoriæ, till a current of mud is produced, which is called, in Campania, "lava d' acqua," and is often more dreaded than an igneous stream (lava di fuoco), from the greater velocity with which it moves. So late as the 27th of October, 1822, one of these alluviums descended the cone of Vesuvius, and, after overspreading much cultivated soil, flowed suddenly into the villages of St. Sebastian and Massa, where, filling the streets and interior of some of the houses, it suffocated seven persons. It will therefore happen very frequently, that,

* See Daubeny's Volcanos, p. 400.

towards the base of a volcanic cone, alternations will be found of lava, alluvium, and showers of ashes.

Mass enveloping Herculaneum and Pompeii.—To which of these two latter divisions the mass enveloping Herculaneum and Pompeii should be referred, has been a question of the keenest controversy; but the discussion might have been shortened, if the combatants had reflected that, whether volcanic sand and ashes were conveyed to the towns by running water, or through the air, during an eruption, the interior of buildings, so long as the roofs remain entire, together with all underground vaults and cellars, could be filled only by an *alluvium*. We learn from history, that a heavy shower of sand, pumice, and lapilli, sufficiently great to render Pompeii and Herculaneum uninhabitable, fell for eight successive days and nights in the year 79, accompanied by violent rains. We ought, therefore, to find a very close resemblance between the strata covering these towns, and those composing the minor cones of the Phlegræan Fields, accumulated rapidly, like Monte Nuovo, during a continued shower of ejected matter; with this difference however, that the strata incumbent on the cities would be horizontal, whereas those in the cones are highly inclined, and that large angular fragments of rock, which are thrown out near the vent, would be wanting at a distance, where small lapilli only can be found. Accordingly, with these exceptions, no identity can be more perfect than the form and distribution of the matter at the base of Monte Nuovo, as laid open by the encroaching sea, and the appearance of the beds superimposed on Pompeii. That city is covered with numerous alternations of different horizontal beds of tuff and lapilli,

for the most part thin, and subdivided into very fine layers. I observed the following section near the Amphitheatre, in November, 1828 — (descending series).

	Feet.	Inches.
1. Black sparkling sand from the eruption of 1822, containing minute regularly formed crystals of augite and tourmaline, from .		2 to 3*
2. Vegetable mould	3	0
3. Brown incoherent tuff, full of *pisolitic globules* in layers, from half an inch to three inches in thickness	1	6
4. Small scoriæ and white lapilli . . .	0	3
5. Brown earthy tuff, with numerous pisolitic globules	0	9
6. Brown earthy tuff, with lapilli divided into layers	4	0
7. Layer of whitish lapilli . . .	0	1
8. Grey solid tuff	0	3
9. Pumice and white lapilli . . .	0	3
	10	4

Many of the ashes in these beds are vitrified and harsh to the touch. Crystals of leucite, both fresh and farinaceous, have been found intermixed.† The depth of the bed of ashes above the houses is variable,

* The last great eruption, in 1822, caused a covering only a few inches thick on Pompeii. Several feet are mentioned by Mr. Forbes.—Ed. Journ. of Science, No. xix. p. 131. Jan. 1829. But he must have measured in spots where it had drifted. The dust and ashes were five feet thick at the top of the crater, and decreased gradually to ten inches at Torre del Annunziata. The size and weight of the ejected fragments diminished very regularly in the same continuous stratum, as the distance from the centre of projection was greater.

† Forbes, ibid. p. 130.

but seldom exceeds twelve or fourteen feet, and it is said that the higher part of the Amphitheatre always projected above the surface; though, if this were the case, it seems inexplicable that the city should never have been discovered till the year 1750. It will be observed, in the above section, that two of the brown half-consolidated tuffs are filled with small pisolitic globules. It is surprising that this circumstance is not alluded to in the animated controversy which the Royal Academy of Naples maintained with one of their members, Signor Lippi, as to the origin of the strata incumbent on Pompeii. The mode of aggregation of these globules has been fully explained by Mr. Scrope, who saw them formed in great numbers, in 1822, by rain falling during the eruption on fine volcanic sand, and sometimes, also, produced like hail in the air, by the mutual attraction of the minutest particles of fine damp sand. Their occurrence, therefore, agrees remarkably well with the account of heavy rain, and showers of sand and ashes, recorded in history, and is opposed to the theory of an alluvium brought from a distance by a flood of water.

Lippi entitled his work, "Fù il fuoco o l' acqua che sotterrò Pompei ed Ercolano?"* and he contended that neither were the two cities destroyed in the year 79, nor by a volcanic eruption, but purely by the agency of water charged with transported matter. His Letters, wherein he endeavoured to dispense, as far as possible, with igneous agency, even at the foot of the volcano, were dedicated, with great propriety, to Werner, and afford an amusing illustration of the polemic style in which geological writers of that day

* Napoli, 1816.

indulged themselves. His arguments were partly of an historical nature, derived from the silence of contemporary historians, respecting the fate of the cities which, as we have already stated, is most remarkable, and partly drawn from physical proofs. He pointed out with great clearness the resemblance of the tufaceous matter in the vaults and cellars at Herculaneum and Pompeii to aqueous alluviums, and its distinctness from ejections which had fallen through the air. Nothing, he observed, but moist pasty matter could have received the impression of a woman's breast, which was found in a vault at Pompeii, or have given the cast of a statue discovered in the theatre at Herculaneum. It was objected to him, that the heat of the tuff in Herculaneum and Pompeii was proved by the carbonization of the timber, corn, papyrus-rolls, and other vegetable substances there discovered: but Lippi replied with truth, that the papyri would have been burnt up, if they had come in contact with fire, and that their being only carbonized was a clear demonstration of their having been enveloped, like fossil wood, in a sediment deposited from water. The Academicians, in their report on his pamphlet, assert, that when the Amphitheatre was first cleared out, the matter was arranged, on the steps, in a succession of concave layers, accommodating themselves to the interior form of the building, just as snow would lie if it had fallen there. This observation is highly interesting, and points to the difference between the stratification of ashes in an open building, and of mud derived from the same in the interior of edifices and cellars. Nor ought we to call the allegation in question, because it could not be substantiated at the time of the controversy, after the matter had been all removed;

although Lippi took advantage of this removal, and met the argument of his antagonists by requiring them to prove the fact.

Pompeii not destroyed by lava.—There is decisive evidence that no stream of lava has ever reached Pompeii since it was first built, although the foundations of the town stand upon the old leucitic lava of Somma; several streams of which, with tuff interposed, have been cut through in excavations. At Herculaneum the case is different, although the substance which fills the interior of the houses and the vaults must have been introduced in a state of mud, like that found in similar situations in Pompeii; yet the superincumbent mass differs wholly in composition and thickness. Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more exposed to be covered, not only by showers of ashes, but by alluviums and streams of lava. Accordingly, masses of both have accumulated on each other above the city, to a depth of nowhere less than 70, and in many places of 112 feet.*

The tuff which envelopes the buildings consists of comminuted volcanic ashes, mixed with pumice. A mask imbedded in this matrix has left a cast, the sharpness of which was compared by Hamilton to those in plaster of Paris; nor was the mask in the least degree scorched, as if it had been imbedded in heated matter. This tuff is porous; and, when first excavated, is soft and easily worked, but acquires a considerable degree of induration on exposure to the air. Above this lowest stratum is placed, according to

* Hamilton's Observations on Mount Vesuvius, p. 94. London, 1774.

Hamilton, "the matter of six eruptions," each separated from the other by veins of good soil. In these soils Lippi states that he collected a considerable number of land shells — an observation which is no doubt correct; for many snails burrow in soft soils, and some Italian species descend, when they hybernate, to the depth of five feet and more from the surface. Della Torre also informs us that there is in one part of this superimposed mass a bed of true siliceous lava (*lava di pietra dura*); and, as no such current is believed to have flowed till near one thousand years after the destruction of Herculaneum, we must conclude, that the origin of a large part of the covering of Herculaneum was long subsequent to the first inhumation of the place. That city, as well as Pompeii, was a seaport. Herculaneum is still very near the shore, but a tract of land, a mile in length, intervenes between the borders of the Bay of Naples and Pompeii. In both cases the gain of land is due to the filling up of the bed of the sea with volcanic matter, and not to elevation by earthquakes, for there has been no change in the relative level of land and sea. Pompeii stood on a slight eminence composed of the lavas of the ancient Vesuvius, and flights of steps led down to the water's edge. The lowermost of these steps are said to be still on an exact level with the sea.

Condition and contents of the buried cities. — After these observations on the nature of the strata enveloping and surrounding the cities, we may proceed to consider their internal condition and contents, so far at least as they offer facts of geological interest. Notwithstanding the much greater depth at which Herculaneum was buried, it was discovered before Pompeii, by the accidental circumstance of a well being sunk,

in 1713, which came right down upon the theatre, where the statues of Hercules and Cleopatra were soon found. Whether this city or Pompeii, both of them founded by Greek colonies, was the most considerable, is not yet determined; but both are mentioned by ancient authors as among the seven most flourishing cities in Campania. The walls of Pompeii were three miles in circumference; but we have, as yet, no certain knowledge of the dimensions of Herculaneum. In the latter place the theatre alone is open for inspection; the Forum, Temple of Jupiter, and other buildings, having been filled up with rubbish as the workmen proceeded, owing to the difficulty of removing it from so great a depth below ground. Even the theatre is only seen by torchlight, and the most interesting information, perhaps, which the geologist obtains there, is the continual formation of stalactite in the galleries cut through the tuff; for there is a constant percolation of water charged with carbonate of lime mixed with a small portion of magnesia. Such mineral waters must, in the course of time, create great changes in many rocks; especially in lavas, the pores of which they may fill with calcareous spar, so as to convert them into amygdaloids. Some geologists, therefore, are unreasonable when they expect that volcanic rocks of remote eras should accord precisely with those of modern date; since it is obvious that many of those produced in our own time will not long retain the same aspect and internal composition.

Both at Herculaneum and Pompeii, temples have been found with inscriptions commemorating the rebuilding of the edifices after they had been thrown

down by an earthquake.* This earthquake happened in the reign of Nero, sixteen years before the cities were overwhelmed. In Pompeii, one fourth of which is now laid open to the day, both the public and private buildings bear testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open. Columns are lying on the ground only half hewn from huge blocks of travertin, and the temple for which they were designed is seen half repaired. In some few places the pavement had sunk in, but in general it was undisturbed, consisting of large irregular flags of lava joined neatly together, in which the carriage wheels have often worn ruts an inch and a half deep. In the wider streets, the ruts are numerous and irregular; in the narrower, there are only two, one on each side, which are very conspicuous. It is impossible not to look with some interest even on these ruts, which were worn by chariot wheels more than seventeen centuries ago; and, independently of their antiquity, it is remarkable to see such deep incisions so continuous in a stone of great hardness. We observe nothing of the kind in the oldest pavements of modern cities.

Small number of skeletons. — A very small number of skeletons have been discovered in either city; and it is clear that most of the inhabitants not only found time to escape, but also to carry with them the principal part of their valuable effects. In the barracks at Pompeii were the skeletons of two soldiers chained to the stocks, and in the vaults of a country-house in the suburbs were the skeletons of seventeen persons, who

* Swinburne and Lalande. Paderni, Phil. Trans. 1758, vol. l. p. 619.

appear to have fled there to escape from the shower of ashes. They were found inclosed in an indurated tuff, and in this matrix was preserved a perfect cast of a woman, perhaps the mistress of the house, with an infant in her arms. Although her form was imprinted on the rock, nothing but the bones remained. To these a chain of gold was suspended, and on the fingers of the skeleton were rings with jewels. Against the sides of the same vault was ranged a long line of earthen amphoræ.

The writings scribbled by the soldiers on the walls of their barracks, and the names of the owners of each house written over the doors, are still perfectly legible. The colours of fresco paintings on the stuccoed walls in the interior of buildings are almost as vivid as if they were just finished. There are public fountains decorated with shells laid out in patterns in the same fashion as those now seen in the town of Naples; and in the room of a painter, who was perhaps a naturalist, a large collection of shells was found, comprising a great variety of Mediterranean species, in as good a state of preservation as if they had remained for the same number of years in a museum. A comparison of these remains with those found so generally in a fossil state would not assist us in obtaining the least insight into the time required to produce a certain degree of decomposition or mineralization; for, although, under favourable circumstances, much greater alteration might doubtless have been brought about in a shorter period, yet the example before us shows that an inhumation of seventeen centuries may sometimes effect nothing towards the reduction of shells to the state in which fossils are usually found.

The wooden beams in the houses at Herculaneum

are black on the exterior, but when cleft open they appear to be almost in the state of ordinary wood, and the progress made by the whole mass towards the state of lignite is scarcely appreciable. Some animal and vegetable substances of more perishable kinds have of course suffered much change and decay, yet the state of conservation of these is truly remarkable. Fishing-nets are very abundant in both cities, often quite entire; and their number at Pompeii is the more interesting from the sea being now, as we stated, a mile distant. Linen has been found at Herculaneum, with the texture well defined; and in a fruiterer's shop in that city were discovered vessels full of almonds, chestnuts, walnuts, and fruit of the "carubiere," all distinctly recognizable from their shape. A loaf, also, still retaining its form, was found in a baker's shop, with his name stamped upon it. On the counter of an apothecary was a box of pills converted into a fine earthy substance; and by the side of it a small cylindrical roll, evidently prepared to be cut into pills. By the side of these was a jar containing medicinal herbs. In 1827, moist olives were found in a square glass case, and "caviare," or roe of a fish, in a state of wonderful preservation. An examination of these curious condiments has been published by Covelli, of Naples, and they are preserved hermetically sealed in the museum there.*

Papyri. — There is a marked difference in the condition and appearance of the animal and vegetable substances found in Pompeii and Herculaneum; those of Pompeii being penetrated by a grey pulverulent tuff, those in Herculaneum seeming to have been first

* Mr. Forbes, Edin. Journ. of Sci., No. xix. p. 130, Jan. 1829.

enveloped by a paste which consolidated round them, and then allowed them to become slowly carbonized. Some of the rolls of papyrus at Pompeii still retain their form; but the writing, and indeed almost all the vegetable matter, appear to have vanished, and to have been replaced by volcanic tuff somewhat pulverulent. At Herculaneum the earthy matter has scarcely ever penetrated; and the vegetable substance of the papyrus has become a thin friable black matter, almost resembling in appearance the tinder which remains when stiff paper has been burnt, in which the letters may still be sometimes traced. The small bundles of papyri, composed of five or six rolls tied up together, had sometimes lain horizontally, and were pressed in that direction, but sometimes they had been placed in a vertical position. Small tickets were attached to each bundle, on which the title of the work was inscribed. In one case only have the sheets been found with writing on both sides of the pages. So numerous are the obliterations and corrections, that many must have been original manuscripts. The variety of handwritings is quite extraordinary: nearly all are written in Greek, but there are a few in Latin. They were almost all found in a suburban villa in the library of one private individual; and the titles of four hundred of those least injured, which have been read, are found to be unimportant works, but all entirely new, chiefly relating to music, rhetoric, and cookery. There are two volumes of Epicurus "On Nature," and the others are mostly by writers of the same school, only one fragment having been discovered, by an opponent of the Epicurean system, Chrysippus.*

* In one of the manuscripts which was in the hands of the interpreters when I visited the museum, the author indulges in

Probability of future discoveries of MSS. — In the opinion of some antiquaries, not one-hundreth part of the city has yet been explored; and the quarters hitherto cleared out, at a great expense, are those where there was the least probability of discovering manuscripts. As Italy could already boast her splendid Roman amphitheatres and Greek temples, it was a matter of secondary interest to add to their number those in the dark and dripping galleries of Herculaneum; and having so many of the masterpieces of ancient art, we could have dispensed with the inferior busts and statues which could alone have been expected to reward our researches in the ruins of a provincial town. But from the moment that it was ascertained that rolls of papyrus preserved in this city could still be deciphered, every exertion ought to have been steadily and exclusively directed towards the discovery of other libraries. Private dwellings should have been searched, before so much labour and expense were consumed in examining public edifices. A small portion of that zeal and enlightened spirit which prompted the late French and Tuscan expedition to Egypt might, long ere this, in a country nearer home, have snatched from oblivion some of the lost works of the Augustan age, or of eminent Greek historians and philosophers. A single roll of papyrus might have disclosed more matter of intense interest than all that was ever written in hieroglyphics.*

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the speculation that all the Homeric personages were allegorical— that Agamemnon was the ether, Achilles the sun, Helen the earth, Paris the air, Hector the moon, &c.

* During my stay at Naples, in 1828, the Neapolitan government, after having discontinued operations for many years, cleared

Stabiæ. — Besides the cities already mentioned, Stabiæ, a small town about six miles from Vesuvius, and near the site of the modern Castel-a-Mare (see map of volcanic district of Naples), was overwhelmed during the eruption of 79. Pliny mentions that, when his uncle was there, he was obliged to make his escape, so great was the quantity of falling stones and ashes. In the ruins of this place, a few skeletons have been found buried in volcanic ejections, together with some antiquities of no great value, and rolls of papyrus, which, like those of Pompeii, were illegible.

Torre del Greco overflowed by lava. — Of the towns hitherto mentioned, Herculaneum alone has been overflowed by a stream of melted matter; but this did not, as we have seen, enter or injure the buildings which were previously enveloped or covered over with tuff. But burning torrents have often taken their course through the streets of Torre del Greco, and consumed or inclosed a large portion of the town in solid rock. It seems probable that the destruction of three thousand of its inhabitants, in 1631, which some accounts attribute to boiling water, was principally due to one of those alluvial floods which we before mentioned: but, in 1737, the lava itself flowed through the eastern side of the town, and afterwards reached the sea; and, in

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out a small portion of Herculaneum, near the sea, where the covering was least thick. After this expense had been incurred, it was discovered that the whole of the ground had been previously examined, near a century before, by the French Prince d'Elbœuf, who had removed every thing of value! Such is the want of system with which operations have always been, and still are, carried on here, that we may expect similar blunders to be made continually.

1794, another current, rolling over the western side, filled the streets and houses, and killed more than four hundred persons. The main street is now quarried through this lava, which supplied building-stones for new houses erected where others had been annihilated. The church was half buried in a rocky mass, but the upper portion served as the foundation of a new edifice.

The number of the population at present is estimated at fifteen thousand; and a satisfactory answer may readily be returned to those who inquire how the inhabitants can be so "inattentive to the voice of time and the warnings of Nature *," as to rebuild their dwellings on a spot so often devastated. No neighbouring site unoccupied by a town, or which would not be equally insecure, combines the same advantages of proximity to the capital, to the sea, and to the rich lands on the flanks of Vesuvius. If the present population were exiled, they would immediately be replaced by another, for the same reason that the Maremma of Tuscany and the Campagna di Roma will never be depopulated, although the malaria fever commits more havoc in a few years than the Vesuvian lavas in as many centuries. The district around Naples supplies one, amongst innumerable examples, that those regions where the surface is most frequently renewed, and where the renovation is accompanied, at different intervals of time, by partial destruction of animal and vegetable life, may nevertheless be amongst the most habitable and delightful on our globe.

I have already made a similar remark when speaking of tracts where aqueous causes are now most active; and the observation applies as well to parts

* Sir H. Davy, Consolations in Travel, p. 66.

of the surface which are the abode of aquatic animals, as to those which support terrestrial species. The sloping sides of Vesuvius give nourishment to a vigorous and healthy population of about eighty thousand souls; and the surrounding hills and plains, together with several of the adjoining isles, owe the fertility of their soil to matter ejected by prior eruptions. Had the fundamental limestone of the Apennines remained uncovered throughout the whole area, the country could not have sustained a twentieth part of its present inhabitants. This will be apparent to every geologist who has marked the change in the agricultural character of the soil the moment he has passed the utmost boundary of the volcanic ejections, as when, for example, at the distance of about seven miles from Vesuvius, he leaves the plain and ascends the declivity of the Sorrentine Hills.

Concluding remarks. — Yet favoured as this region has been by Nature from time immemorial, the signs of the changes imprinted on it during the period that it has served as the habitation of man may appear in after-ages to indicate a series of unparalleled disasters. Let us suppose that at some future time the Mediterranean should form a gulf of the great ocean, and that the tidal current should encroach on the shores of Campania, as it now advances upon the eastern coast of England; the geologist will then behold the towns already buried, and many more which will evidently be entombed hereafter, laid open in the steep cliffs, where he will discover buildings superimposed above each other, with thick intervening strata of tuff or lava — some unscathed by fire, like those of Herculaneum and Pompeii; others half melted down, as in Torre del Greco; and many shattered and thrown

about in strange confusion, as in Tripergola. Among the ruins will be seen skeletons of men, and impressions of the human form stamped in solid rocks of tuff. Nor will the signs of earthquakes be wanting. The pavement of part of the Domitian Way, and the Temple of the Nymphs, submerged at high tide, will be uncovered at low water, the columns remaining erect and uninjured. Other temples which had once sunk down, like that of Serapis, will be found to have been upraised again by subsequent movements. If they who study these phenomena, and speculate on their causes, assume that there were periods when the laws of Nature differed from those established in their own time, they will scarcely hesitate to refer the wonderful monuments in question to those primeval ages. When they consider the numerous proofs of reiterated catastrophes to which the region was subject, they may, perhaps, commiserate the unhappy fate of beings condemned to inhabit a planet during its nascent and chaotic state, and feel grateful that their favoured race has escaped such scenes of anarchy and misrule.

Yet what was the real condition of Campania during those years of dire convulsion? "A climate where heaven's breath smells sweet and wooingly — a vigorous and luxuriant nature unparalleled in its productions — a coast which was once the fairy land of poets, and the favourite retreat of great men. Even the tyrants of the creation loved this alluring region, spared it, adorned it, lived in it, died in it."* The inhabitants, indeed, have enjoyed no immunity from the calamities which are the lot of mankind; but the principal evils which they have suffered must be attributed to moral, not to physical, causes — to disastrous events over

* Forsyth's Italy, vol. ii.

which man might have exercised a control, rather than to the inevitable catastrophes which result from subterranean agency. When Spartacus encamped his army of ten thousand gladiators in the old extinct crater of Vesuvius, the volcano was more justly a subject of terror to Campania, than it has ever been since the rekindling of its fires.

CHAPTER XII.

ETNA — SKAPTAR JOKUL — JORULLO.

External physiognomy of Etna — Lateral cones — Their successive obliteration — Early eruptions of Etna — Monti Rossi in 1669 — Great Fissure of S. Lio — Towns overflowed by lava — Part of Catania destroyed (p. 171.) — Mode of advance of a current of lava — Excavation of a church under lava — Subterranean caverns — Linear direction of cones formed in 1811 and 1819 — Flood produced in 1755 by the melting of snow during an eruption — A glacier covered by lava on Etna — Volcanic eruptions in Iceland (p. 179.) — New island thrown up in 1783 — Lava currents of Skaptár Jokul in same year — Their immense volume — Eruption of Jorullo in Mexico (p. 186.) — Humboldt's Theory of the convexity of the Plain of Malpais.

External physiognomy of the cone. — Having entered into a detailed historical account of the changes in the volcanic district round Naples, I shall allude in a more cursory manner to some of the circumstances of principal interest in the history of other volcanic mountains. After Vesuvius, our most authentic records relate to Etna, which rises near the sea in solitary grandeur to the height of nearly eleven thousand feet,*

* In 1815, Captain Smyth ascertained, trigonometrically, that the height of Etna was 10,874 feet. The Catanians, disappointed that their mountain had lost nearly 2000 feet of the height assigned to it by Recupero, refused to acquiesce in the decision. Afterwards, in 1824, Sir J. Herschel, not being aware of Captain

the mass being chiefly composed of volcanic matter ejected above the surface of the water. The base of the cone is almost circular, and eighty-seven English miles in circumference; but if we include the whole district over which its lavas extend, the circuit is probably twice that extent.

Divided into three regions. — The cone is divided by nature into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The first of these, comprising the delightful country around the skirts of the mountain, is well cultivated, thickly inhabited, and covered with olives, vines, corn, fruit-trees, and aromatic herbs. Higher up, the woody region encircles the mountain — an extensive forest, six or seven miles in width, affording pasturage for numerous flocks. The trees are of various species, the chestnut, oak, and pine being most luxuriant; while in some tracts are groves of cork and beech. Above the forest is the desert region, a waste of black lava and scoriæ; where, on a kind of plain, rises the cone to the height of about eleven hundred feet, from which sulphureous vapours are continually evolved. The most grand and original feature in the physiognomy of Etna is the multitude of minor cones which are distributed over its flanks, and which are most abundant in the woody region. These, although they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain,

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Smyth's conclusions, determined, by careful barometrical measurement, that the height was $10{,}872\frac{1}{2}$ feet. This singular agreement of results so differently obtained was spoken of by Herschel as "a happy accident;" but Dr. Wollaston remarked that "it was one of those accidents which would not have happened to two fools."

would, nevertheless, be deemed hills of considerable altitude in almost any other region.

Cones produced by lateral eruptions.—Without enumerating numerous monticules of ashes thrown out at different points, there are about eighty of these secondary volcanos, of considerable dimensions; fifty-two on the west and north, and twenty-seven on the east side of Etna. One of the largest, called Monte Minardo, near Bronte, is upwards of 700 feet in height, and a double hill near Nicolosi, called Monti Rossi, formed in 1669, is 450 feet high, and the base two miles in circumference; so that it somewhat exceeds in size Monte Nuovo, before described. Yet it ranks only as a cone of the second magnitude amongst those produced by the lateral eruptions of Etna. On looking down from the lower borders of the desert region, these volcanos present us with one of the most delightful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which is generally broken down. There are, indeed, few objects in nature more picturesque than a wooded volcanic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines; while those at a lower elevation are adorned with chestnuts, oak, beech, and holm.

Successive obliteration of these cones. — The history of the eruptions of Etna, imperfect and interrupted as it is, affords, nevertheless, a full insight into the manner in which the whole mountain has successively attained its present magnitude and internal structure. The

principal cone has more than once fallen in and been reproduced. In 1444 it was 320 feet high, and fell in after the earthquakes of 1537. In the year 1693, when a violent earthquake shook the whole of Sicily, and killed sixty thousand persons, the cone lost so much of its height, says Boccone, that it could not be seen from several places in Valdemone, from which it was before visible. The greater number of eruptions happen either from the great crater, or from lateral openings in the desert region. When hills are thrown up in the middle zone, and project beyond the general level, they gradually lose their height during subsequent eruptions; for when lava runs down from the upper parts of the mountain, and encounters any of these hills, the stream is divided, and flows round them so as to elevate the gently sloping grounds from which they rise. In this manner a deduction is often made at once of twenty or thirty feet, or even more, from their height. Thus, one of the minor cones, called Monte Peluso, was diminished in altitude by a great lava stream which encircled it in 1444; and another current has recently taken the same course — yet this hill still remains four or five hundred feet high.

There is a cone called Monte Nucilla, near Nicolosi, round the base of which several successive currents have flowed, and showers of ashes have fallen, since the time of history, till at last, during an eruption in 1536, the surrounding plain was so raised, that the top of the cone alone was left projecting above the general level. Monte Nero, situated above the Grotta dell' Capre, was in 1766 almost submerged by a current; and Monte Capreolo afforded, in the year 1669, a curious example of one of the last stages of obliteration: for a lava stream, descending on a high ridge

which had been built up by the continued superposition of successive lavas, flowed directly into the crater, and nearly filled it. The lava, therefore, of each new lateral cone tends to detract from the relative height of lower cones above their base: so that the flanks of Etna, sloping with a gentle inclination, envelop in succession a great multitude of minor volcanos, while new ones spring up from time to time; and this has given to the older parts of the mountain, as seen in some sections two or three thousand feet perpendicular, a complex and highly interesting internal structure.

Early eruptions of Etna. — Etna appears to have been in activity from the earliest times of tradition; for Diodorus Siculus mentions an eruption which caused a district to be deserted by the Sicani before the Trojan war. Thucydides informs us *, that in the sixth year of the Peloponnesian war, or in the spring of the year 425 B. C., a lava stream ravaged the environs of Catania, and this, he says, was the third eruption which had happened in Sicily since the colonization of that island by the Greeks. The second of the three eruptions alluded to by the historian took place in the year 475 B. C., and was that so poetically described by Pindar, two years afterwards, in his first Pythian ode:—

κιων
Δ'ουρανια συνεχει
Νιφοεσσ' Αἰτνα, πανετες
Χιονος ὀξειας τιθηνα·

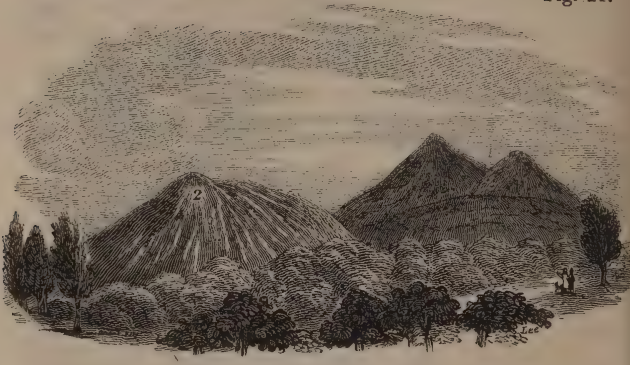
In these and the seven verses which follow, a graphic description is given of Etna, such as it appeared five centuries before the Christian era, and such as it

* Book iii., at the end.

has been seen when in eruption in modern times. The poet is only making a passing allusion to the Sicilian volcano, as the mountain under which Typhœus lay buried, yet by a few touches of his master hand every striking feature of the scene has been faithfully pourtrayed. We are told of "the snowy Etna, the pillar of heaven,—the nurse of everlasting frost, in whose deep caverns lie concealed the fountains of unapproachable fire — a stream of eddying smoke by day — a bright and ruddy flame by night; and burning rocks rolled down with loud uproar into the sea."

Eruption of 1669—*Monti Rossi formed.*—The great eruption which happened in the year 1669 is the first which claims particular attention. An earthquake had levelled to the ground all the houses in Nicolosi, a town situated near the lower margin of the woody region, about twenty miles from the summit of Etna, and ten from the sea at Catania. Two gulphs then opened near that town, from whence sand and scoriæ were thrown up in such quantity, that, in the course of three or four months, a double cone was formed, called Monti Rossi, about 450 feet high. But the most extraordinary phenomenon occurred at the commencement of the convulsion in the plain of S. Lio. A fissure six feet broad, and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was from north to south, and its length twelve miles. It emitted a most vivid light. Five other parallel fissures of considerable length afterwards opened one after the other, and emitted smoke, and gave out bellowing sounds which were heard at the distance of

Fig. 21.



Minor cones on the flanks of Etna.

1. Monti Rossi, near Nicolosi, formed in 1669.
2. Vampeluso? *

forty miles. This case seems to present the geologist with an illustration of the manner in which those continuous dikes of vertical porphyry were formed which are seen to traverse some of the older lavas of Etna; for the light emitted from the great rent of S. Lio appears to indicate that the fissure was filled to a certain height with incandescent lava, probably to the height of an orifice not far distant from Monti Rossi, which at that time opened and poured out a lava current. When the melted matter in such a rent has cooled, it must become a solid wall or dike, intersecting the older rocks of which the mountain is composed.

The lava current above alluded to soon reached in its

* The hill which I have here introduced was called by my guide Vampolara, but the name given in the text is the nearest to this which I find in Gemmellaro's Catalogue of Minor Cones.

course a minor cone called Mompiliere, at the base of which it entered a subterranean grotto, communicating with a suite of those caverns which are so common in the lavas of Etna. Here it appears to have melted down some of the vaulted foundations of the hill, so that the whole of that cone became slightly depressed and traversed by numerous open fissures.

Part of Catania destroyed.—The lava, after overflowing fourteen towns and villages, some having a population of between three and four thousand inhabitants, arrived at length at the walls of Catania. These had been purposely raised to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was sixty feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. The wall, however, was not thrown down, but was discovered long afterwards, by excavations made in the rock by the Prince of Biscari; so that the traveller may now see the solid lava curling over the top of the rampart as if still in the very act of falling.

This great current had performed a course of fifteen miles before it entered the sea, where it was still six hundred yards broad, and forty feet deep. It covered some territories in the environs of Catania, which had never before been visited by the lavas of Etna. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava streams, was by the occasional fissuring of the solid walls. A gentleman of Catania, named Pappalardo, desiring to secure the city from the approach of the threatening torrent, went out with a party of fifty men whom he had dressed in skins to protect them from the heat, and armed with iron crows and hooks. They broke open one of the solid walls which flanked

the current near Belpasso, and immediately forth issued a rivulet of melted matter which took the direction of Paternò; but the inhabitants of that town, being alarmed for their safety, took up arms and put a stop to farther operations.*

As another illustration of the solidity of the walls of an advancing lava stream, I may mention an adventure related by Recupero, who, in 1766, had ascended a small hill formed of ancient volcanic matter, to behold the slow and gradual approach of a fiery current, two miles and a half broad; when suddenly two small threads of liquid matter issuing from a crevice detached themselves from the main stream, and ran rapidly towards the hill. He and his guide had just time to escape, when they saw the hill, which was fifty feet in height, surrounded, and in a quarter of an hour melted down into the burning mass, so as to flow on with it.

But it must not be supposed that this complete fusion of rocky matter coming in contact with lava is of universal, or even common, occurrence. It probably happens when fresh portions of incandescent matter come successively in contact with fusible materials. In many of the dikes which intersect the tuffs and lavas of Etna, there is scarcely any perceptible alteration effected by heat on the edges of the horizontal beds, in contact with the vertical and more crystalline mass. On the site of Mompiliere, one of the towns overflowed in the great eruption above described, an excavation was made in 1704; and by immense labour the workmen reached, at the depth of thirty-five feet, the gate of the principal church, where there were three statues, held in high veneration. One of these, together with

* Ferrara, Descriz. dell' Etna, p. 108.

a bell, some money, and other articles, were extracted in a good state of preservation from beneath a great arch formed by the lava. It seems very extraordinary that any works of art, not encased with tuff, like those in Herculaneum, should have escaped fusion in hollow spaces left open in this lava current, which was so hot at Catania eight years after it entered the town, that it was impossible to hold the hand in some of the crevices.

Subterranean caverns on Etna. — Mention was made of the entrance of a lava stream into a subterranean grotto, whereby the foundations of a hill were partially undermined. Such underground passages are among the most curious features on Etna, and appear to have been produced by the hardening of the lava, during the escape of great volumes of elastic fluids, which are often discharged for many days in succession, after the crisis of the eruption is over. Near Nicolosi, not far from Monti Rossi, one of these great openings may be seen, called the Fossa della Palomba, 625 feet in circumference at its mouth, and seventy-eight deep. After reaching the bottom of this, we enter another dark cavity, and then others in succession, sometimes descending precipices by means of ladders. At length the vaults terminate in a great gallery ninety feet long, and from fifteen to fifty broad, beyond which there is still a passage, never yet explored; so that the extent of these caverns remains unknown.* The walls and roofs of these great vaults are composed of rough and bristling scoriæ, of the most fantastic forms.

Eruption of 1811. — I shall now proceed to offer some observations on the two last eruptions in 1811

* Ferrara, Descriz. dell' Etna. Palermo, 1818.

and 1819.* It appears, from the relation of Signor Gemmellaro, who witnessed the phenomena, that the great crater in 1811 first testified, by its loud detonations, that the lava had ascended to near the summit of the mountain. A violent shock was then felt, and a stream broke out from the side of the cone, at no great distance from its apex. Shortly after this had ceased to flow, a second stream burst forth at another opening, considerably below the first; then a third still lower, and so on till seven different issues had been thus successively formed, all lying upon the same straight line. It has been supposed that this line was a perpendicular rent in the internal framework of the mountain, which rent was probably not produced at one shock, but prolonged successively downwards, by the lateral pressure and intense heat of the internal column of lava, as it subsided by gradual discharge through each vent.†

Eruption of 1819. — In 1819 three large mouths or caverns opened very near those which were formed in the eruptions of 1811, from which flames, red-hot cinders, and sand, were thrown up with loud explosions. A few minutes afterwards another mouth opened below, from which flames and smoke issued; and finally a fifth, lower still, whence a torrent of lava flowed, which spread itself with great velocity over the deep and broad valley called "Val del Bove." This stream flowed two miles in the first twenty-four hours, and nearly as far in the succeeding day and night.

* Since this was written for the 1st edition of this work, another eruption has occurred. In 1832, the lava flowed down on the west side of Etna to within two miles of Bronte.

† Scrope on Volcanos, p.153.

The three original mouths at length united into one large crater, and sent forth lava, as did the inferior apertures, so that an enormous torrent poured down the "Val del Bove." When it arrived at a vast and almost perpendicular precipice, at the head of the valley of Calanna, it poured over in a cascade, and, being hardened in its descent, made an inconceivable crash as it was dashed against the bottom. So immense was the column of dust raised by the abrasion of the tufaceous hill over which the hardened mass descended, that the Catanians were in great alarm, supposing a new eruption to have burst out in the woody region, exceeding in violence that near the summit of Etna.

Mode of advance of the lava.—Of the cones thrown up during this eruption, not more than two are of sufficient magnitude to be numbered among those eighty which were before described as adorning the flanks of Etna. The surface of the lava which deluged the "Val del Bove" consists of rocky and *angular blocks*, tossed together in the utmost disorder. Nothing can be more rugged, or more unlike the smooth and even superficies which those who are unacquainted with volcanic countries may have pictured to themselves, in a mass of matter which had consolidated from a liquid state. Mr. Scrope observed this current in the year 1819, slowly advancing down a considerable slope, at the rate of about a yard an hour, nine months after its first emission. The lower stratum being arrested by the resistance of the ground, the upper or central part gradually protruded itself, and being unsupported fell down. This in its turn was covered by a mass of more liquid lava, which swelled over it from above. The current had all the appearance of a huge heap of

rough and large cinders rolling over and over upon itself by the effect of an extremely slow propulsion from behind. The contraction of the crust as it solidified, and the friction of the scoriform cakes against one another, produced a crackling sound. Within the crevices a dull red heat might be seen by night, and vapour issuing in considerable quantity was visible by day.*

Flood produced by the melting of snow by lava.—The erosive and transporting power of running water is rarely exerted on Etna with great force, the rain which falls being immediately imbibed by the porous lavas; so that, vast as is the extent of the mountain, it feeds only a few small rivulets, and these, even, are dry throughout the greater portion of the year. The enormous rounded boulders, therefore, of trachyte and basalt, a line of which can be traced from the sea, from near Giardini, by Mascali, and Zafarana, to the "Val del Bove," would offer a perplexing problem to the geologist, if history had not preserved the memorials of a tremendous flood which happened in this district in the year 1755. It appears that two streams of lava flowed in that year, on the 2nd of March, from the highest crater: they were immediately precipitated upon an enormous mass of snow, which then covered the whole mountain, and was extremely deep near the summit. The sudden melting of this frozen mass, by a fiery torrent three miles in length, produced a frightful inundation, which devastated the sides of the mountain for eight miles in length, and afterwards covered the lower flanks of Etna, where they were less steep, together with the plains near the sea, with great deposits of sand, scoriæ, and blocks of lava.

* Scrope on Volcanos, p. 102.

Many absurd stories circulated in Sicily respecting this event, such as that the water was boiling, and that it was vomited from the highest crater; that it was as salt as the sea, and full of marine shells; but these were mere inventions, to which Recupero, although he relates them as tales of the mountaineers, seems to have attached rather too much importance.

Floods of considerable violence have also been produced on Etna by the fall of heavy rains, aided, probably, by the melting of snow. By this cause alone, in 1761, sixty of the inhabitants of Acicatena were killed, and many of their houses swept away.*

Glacier covered by a lava stream.— A remarkable discovery has lately been made on Etna of a great mass of ice, preserved for many years, perhaps for centuries, from melting, by the singular accident of a current of red-hot lava having flowed over it. The following are the facts in attestation of a phenomenon which must at first sight appear of so paradoxical a character. The extraordinary heat experienced in the South of Europe, during the summer and autumn of 1828, caused the supplies of snow and ice which had been preserved in the spring of that year, for the use of Catania and the adjoining parts of Sicily and the island of Malta, to fail entirely. Great distress was consequently felt for want of a commodity regarded in those countries as one of the necessaries of life rather than an article of luxury, and the abundance of which contributes in some of the larger cities to the salubrity of the water and the general health of the community. The magistrates of Catania applied to Signor M. Gemmellaro, in the hope that his local

* Ferrara. Descriz. dell' Etna, p. 116.

knowledge of Etna might enable him to point out some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor were they disappointed; for he had long suspected that a small mass of perennial ice at the foot of the highest cone was part of a large and continuous glacier covered by a lava current. Having procured a large body of workmen he quarried into this ice, and proved the superposition of the lava for several hundred yards, so as completely to satisfy himself that nothing but the subsequent flowing of the lava over the ice could account for the position of the glacier. Unfortunately for the geologist, the ice was so extremely hard, and the excavation so expensive, that there is no probability of the operations being renewed.

On the first of December, 1828, I visited this spot, which is on the south-east side of the cone, and not far above the Casa Inglese; but the fresh snow had already nearly filled up the new opening, so that it had only the appearance of the mouth of a grotto. I do not, however, question the accuracy of the conclusion of Signor Gemmellaro, who being well acquainted with all the appearances of drift snow in the fissures and cavities of Etna, had recognized, even before the late excavations, the peculiarity of the position of the ice in this locality. We may suppose that at the commencement of the eruption, a deep mass of drift snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ is well known to be an extremely bad conductor of heat; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches

thick over the snow, which effectually prevents the heat of the sun from penetrating.

Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had consolidated, we may then readily conceive that a glacier thus protected, at the height of ten thousand feet above the level of the sea, would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below. When I visited the great crater in the beginning of winter, (December 1st, 1828,) I found the crevices in the interior encrusted with thick ice, and in some cases hot vapours were actually streaming out between masses of ice and the rugged and steep walls of the crater.

After the discovery of Signor Gemmellaro, it would not be surprising to find in the cones of the Icelandic volcanos, which are covered for the most part with perpetual snow, repeated alternations of lava streams and glaciers.

Volcanic eruptions in Iceland. — With the exception of Etna and Vesuvius, the most complete chronological records of a series of eruptions are those of Iceland; for their history reaches as far back as the ninth century of our era; and, from the beginning of the twelfth century, there is clear evidence that, during the whole period, there has never been an interval of more than forty, and very rarely one of twenty years, without either an eruption or a great earthquake. So intense is the energy of the volcanic action in this region, that some eruptions of Hecla have lasted six years without ceasing. Earthquakes have often shaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels,

and the appearance of new lakes.* New islands have often been thrown up near the coast, some of which still exist; while others have disappeared, either by subsidences or the action of the waves.

In the interval between eruptions, innumerable hot springs afford vent to subterranean heat, and solfataras discharge copious streams of inflammable matter. The volcanos in different parts of this island are observed, like those of the Phlegræan Fields, to be in activity by turns, one vent often serving for a time as a safety-valve to the rest. Many cones are often thrown up in one eruption, and in this case they take a linear direction, running generally from north-east to south-west, from the north-eastern part of the island, where the volcano Krabla lies, to the promontory Reykianas.

New island thrown up in 1783.—The convulsions of the year 1783 appear to have been more tremendous than any recorded in the modern annals of Iceland; and the original Danish narrative of the catastrophe, drawn up in great detail, has since been substantiated by several English travellers, particularly in regard to the prodigious extent of country laid waste, and the volume of lava produced.† About a month previous

* Von Hoff, vol. ii. p. 393.

† The first narrative of the eruption was drawn up by Stephensen, then Chief Justice in Iceland, appointed Commissioner by the King of Denmark, for estimating the damage done to the country, that relief might be afforded to the sufferers. Henderson was enabled to correct some of the measurements given by Stephensen, of the depth, width, and length of the lava currents, by reference to the MS. of Mr. Paulson, who visited the tract in 1794, and examined the lava with attention. (Journal of a Residence in Iceland, &c. p. 229.) Some of the principal facts are also corroborated by Dr. Hooker, in his "Tour in Iceland," vol. ii. p. 128.

to the eruption on the main land, a submarine volcano burst forth in the sea in lat. 63° 25′ N. long. 23° 44′ W. at a distance of thirty miles in a south-west direction from Cape Reykianas, and ejected so much pumice, that the ocean was covered with that substance to the distance of 150 miles, and ships were considerably impeded in their course. A new island was thrown up, consisting of high cliffs, within which fire, smoke, and pumice were emitted from two or three different points. This island was claimed by his Danish Majesty, who denominated it Nyöe, or the New Island; but before a year had elapsed, the sea resumed its ancient domain, and nothing was left but a reef of rocks from five to thirty fathoms under water.

Great eruption of Skaptár Jokul. — Earthquakes, which had long been felt in Iceland, became violent on the 11th of June, when Skaptár Jokul, distant nearly two hundred miles from Nyöe, threw out a torrent of lava which flowed down into the river Skaptâ, and completely dried it up. The channel of the river was between high rocks, in many places from four hundred to six hundred feet in depth, and near two hundred in breadth. Not only did the lava fill up this great defile to the brink, but it overflowed the adjacent fields to a considerable extent. The burning flood, on issuing from the confined rocky gorge, was then arrested for some time by a deep lake, which formerly existed in the course of the river, between Skaptardal and Aa, which it entirely filled. The current then advanced again, and reaching some ancient lava full of subterraneous caverns, penetrated and melted down part of it; and in some places, where the steam could not gain vent, it blew up the rock, throwing fragments to the height of more than 150 feet. On the 18th of

June, another ejection of liquid lava rushed from the volcano, which flowed down with amazing velocity over the surface of the first stream. By the damming up of the mouths of some of the tributaries of the Skaptâ, many villages were completely overflowed with water, and thus great destruction of property was caused. The lava, after flowing for several days, was precipitated down a tremendous cataract called Stapafoss, where it filled a profound abyss, which that great waterfall had been hollowing out for ages, and, after this the fiery current again continued its course.

On the 3rd of August, fresh floods of lava still pouring from the volcano, a new branch was sent off in a different direction; for the channel of the Skaptâ was now so entirely choked up, and every opening to the west and north so obstructed, that the melted matter was forced to take a new course, so that it ran in a south-east direction, and discharged itself into the bed of the river Hverfisfliot, where a scene of destruction scarcely inferior to the former was occasioned. These Icelandic lavas (like the ancient streams which are met with in Auvergne, and other provinces of Central France,) are stated by Stephensen to have accumulated to a prodigious depth in narrow rocky gorges; but when they came to wide alluvial plains, they spread themselves out into broad burning lakes, sometimes from twelve to fifteen miles wide, and one hundred feet deep. When the "fiery lake" which filled up the lower portion of the valley of the Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills from whence the Skaptâ takes its rise. This affords a parallel case to one which can be shown to have happened at a remote era in the volcanic region of the Vivarais in France, where lava

issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up the channel of the river Ardêche.

The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont Dor in Auvergne, where more modern lava currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterwards, in 1794, he found columns of smoke still rising from parts of the lava, and several rents filled with hot water.*

Although the population of Iceland was very much scattered, and did not exceed fifty thousand, no less than twenty villages were destroyed, besides those inundated by water; and more than nine thousand human beings perished, together with an immense number of cattle, partly by the depredations of the lava, partly by the noxious vapours which impregnated the air, and, in part, by the famine caused by showers of ashes throughout the island, and the desertion of the coasts by the fish.

Immense volume of the lava.— But the extraordinary volume of melted matter produced in this eruption deserves the particular attention of the geologist. Of the two branches, which flowed in nearly opposite directions, the greatest was fifty, and the lesser forty miles in length. The extreme breadth which the Skaptâ branch attained in the low countries was from

* Henderson's Journal, &c. p. 228.

twelve to fifteen miles, that of the other about seven. The ordinary height of both currents was one hundred feet, but in narrow defiles it sometimes amounted to six hundred. A more correct idea will be formed of the dimensions of the two streams, if we consider how striking a feature they would now form in the geology of England, had they been poured out on the bottom of the sea after the deposition, and before the elevation of our secondary and tertiary rocks. The same causes which have excavated valleys through parts of our marine strata, once continuous, might have acted with equal force on the igneous rocks, leaving, at the same time, a sufficient portion undestroyed to enable us to discover their former extent. Let us, then, imagine the termination of the Skaptâ branch of lava to rest on the escarpment of the inferior and middle oolite, where it commands the vale of Gloucester. The great platform might be one hundred feet thick, and from ten to fifteen miles broad, exceeding any which can be found in Central France. We may also suppose great tabular masses to occur at intervals, capping the summit of the Cotswold Hills between Gloucester and Oxford, by Northleach, Burford, and other towns. The wide valley of the Oxford clay would then occasion an interruption for many miles; but the same rocks might recur on the summit of Cumnor and Shotover Hills, and all the other oolitic eminences of that district. On the chalk of Berkshire, extensive plateaus, six or seven miles wide, would again be formed; and, lastly, crowning the highest sands of Highgate and Hampstead, we might behold some remnants of the current five or six hundred feet in thickness, causing those hills to rival, or even to surpass, in height, Salisbury Craigs and Arthur's Seat.

The distance between the extreme points here indicated would not exceed ninety miles in a direct line; and we might then add, at the distance of nearly two hundred miles from London, along the coast of Dorsetshire and Devonshire for example, a great mass of igneous rocks, to represent those of contemporary origin, which were produced beneath the level of the sea, where the island of Nyöe rose up.

Volume of ancient and modern flows of lava compared.—Yet, gigantic as must appear the scale of these modern volcanic operations, we must be content to regard them as perfectly insignificant in comparison to currents of the primeval ages, if we embrace the theoretical views of some geologists of great celebrity. Thus, we are informed by Professor Brongniart, in his last work, that "aux époques géognostiques anciennes, tous les phénomènes géologiques se passoient dans des dimensions *centuples* de celles qu'ils présentent aujourd'hui."* Had Skaptár Jokul therefore been a volcano of the olden time, it would have poured forth lavas at a single eruption, a hundred times more voluminous than those which were witnessed by the present generation in 1783. But this can never have been intended by M. Brongniart; for were we to multiply the two currents before described by a hundred, and first assume that their height and breadth remain the same, they would stretch out to the length of nine thousand miles, or about half as far again as from the pole to the equator. If, on the other hand, we suppose their length and breadth to remain the same, and multiply their height in an equal proportion, the mean

* Tableau des Terrains qui composent l'Écorce du Globe, p. 52. Paris, 1829.

elevation of the volcanic mass becomes ten thousand feet, and its greatest more than double that of the Himalaya mountains. It will immediately be granted that, among the older formations, no igneous rock of such colossal magnitude has yet been met with; nay, it would be most difficult to point out a mass of ancient date distinctly referrible to a single eruption, which should even rival in volume the matter poured out from Skaptár Jokul in 1783.

Eruption of Jorullo in 1759. — As another example of the stupendous scale of modern volcanic eruptions, I may mention that of Jorullo in Mexico, in 1759. The great region to which this mountain belongs has already been described. The plain of Malpais forms part of an elevated platform, between two and three thousand feet above the level of the sea, and is bounded by hills composed of basalt, trachyte, and volcanic tuff, clearly indicating that the country had previously, though probably at a remote period, been the theatre of igneous action. From the era of the discovery of the New World to the middle of the last century, the district had remained undisturbed, and the space, now the site of the volcano, which is thirty-six leagues distant from the nearest sea, was occupied by fertile fields of sugar-cane and indigo, and watered by the two brooks Cuitimba and San Pedro. In the month of June, 1759, hollow sounds of an alarming nature were heard, and earthquakes succeeded each other for two months, until, in September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm which ran in the direction from N.N.E. to S.S.W. The least of these cones was 300

feet in height; and Jorullo, the central volcano, was elevated 1600 feet above the level of the plain. It sent forth great streams of basaltic lava, containing included fragments of granitic rocks, and its ejections did not cease till the month of February, 1760.

Humboldt visited the country more than 40 years after this occurrence, and was informed by the Indians, that when they returned, long after the catastrophe, to the plain, they found the ground uninhabitable from the excessive heat. When he himself visited the place, there appeared, around the base of the cones, and spreading from them, as from a centre, over an extent of four square miles, a mass of matter 550 feet in height, in a convex form, gradually sloping in all directions towards the plain. This mass was still in a heated state, the temperature in the fissures being on the decrease from year to year, but in 1780 it was still sufficient to light a cigar at the depth of a few inches. On this convex protuberance were thousands of flattish conical mounds, from six to nine feet high, which, as well as large fissures traversing the plain, acted as fumeroles, giving out clouds of sulphuric acid and hot aqueous vapour. The two small rivers before mentioned disappeared during the eruption, losing themselves below the eastern extremity of the plain, and reappearing as hot springs at its western limit.

Cause of the convexity of the plain of Malpais.— Humboldt attributed the convexity of the plain to inflation from below; supposing the ground, for four square miles in extent, to have risen up in the shape of a bladder to the elevation of 550 feet above the plain in the highest part. But this theory is by no means borne out by the facts described; and it is the more necessary to scrutinize closely the proofs relied

on, because the opinion of Humboldt appears to have been received as if founded on direct observation, and has been made the groundwork of other bold and extraordinary theories. Mr. Scrope has suggested that the phenomena may be accounted for far more naturally, by supposing that lava flowing simultaneously from the different orifices, and principally from Jorullo, united into a sort of pool or lake. As they were poured forth on a surface previously flat, they would, if their liquidity was not very great, remain thickest and deepest near their source, and diminish in bulk from thence towards the limits of the space which they covered. Fresh supplies were probably emitted successively during the course of an eruption *which lasted a year;* and some of these, resting on those first emitted, might only spread to a small distance from the foot of the cone, where they would necessarily accumulate to a great height.

The showers, also, of loose and pulverulent matter from the six craters, and principally from Jorullo, would be composed of heavier and more bulky particles near the cones, and would raise the ground at their base, where, mixing with rain, they might have given rise to the stratum of black clay which is described as covering the lava. The small conical mounds (called "hornitos," or little ovens) may resemble those five or six small hillocks which existed in 1823 on the Vesuvian lava, and sent forth columns of vapour, having been produced by the disengagement of elastic fluids heaving up small dome-shaped masses of lava. The fissures mentioned by Humboldt as of frequent occurrence, are such as might naturally accompany the consolidation of a thick bed of lava, contracting as it congeals; and the disappearance of

rivers is the usual result of the occupation of the lower part of a valley or plain by lava, of which there are many beautiful examples in the old lava-currents of Auvergne. The heat of the "hornitos" is stated to have diminished from the first; and Mr. Bullock, who visited the spot many years after Humboldt, found the temperature of the hot spring very low,—a fact which seems clearly to indicate the gradual congelation of a subjacent bed of lava, which from its immense thickness may have been enabled to retain its heat for half a century. The reader may be reminded, that when we thus suppose the lava near the volcano to have been, together with the ejected ashes, more than five hundred feet in depth, we merely assign a thickness which the current of Skaptár Jokul attained in some places in 1783.

Hollow sound of the plain when struck.—Another argument adduced in support of the theory of inflation from below, was, the hollow sound made by the steps of a horse upon the plain; which, however, proves nothing more than that the materials of which the convex mass is composed are light and porous. The sound called "rimbombo" by the Italians is very commonly returned by *made ground* when struck sharply; and has been observed not only on the sides of Vesuvius and other volcanic cones where there is a cavity below, but in plains such as the Campagna di Roma, composed in a great measure of tuff and porous volcanic rocks. The reverberation, however, may perhaps be assisted by grottos and caverns, for these may be as numerous in the lavas of Jorullo as in many of those of Etna; but their existence would lend no countenance to the hypothesis of a great arched

cavity, four square miles in extent, and in the centre 550 feet high.*

No recent eruptions of Jorullo.—In a former edition I stated that I had been informed by Captain Vetch, that in 1819 a tower at Guadalaxara was thrown down by an earthquake, and that ashes, supposed to have come from Jorullo, fell at the same time at Guanaxuato, a town situated 140 English miles from the volcano. There appears, however, to have been a mistake in the statement; for Mr. Burkart, a German director of mines, who examined Jorullo in 1827, ascertained that there had been no eruption there since Humboldt's visit in 1803. He went to the bottom of the crater, and observed a slight evolution of sulphurous acid vapours, but the "hornitos" had entirely ceased to send forth steam. During the twenty-four years intervening between his visit and that of Humboldt, vegetation had made great progress on the flanks of the new hills, the rich soil of the surrounding country was once more covered with luxuriant crops of sugar-cane and indigo, and there was an abundant growth of natural underwood on all the uncultivated tracts.†

* See Scrope on Volcanos, p. 267.

† Leonhard and Bronn's Neues Jahrbuch, 1835, p. 36.

CHAPTER XIII.

Volcanic archipelagos — The Canaries—Eruptions in Teneriffe — Cones thrown up in Lancerote in 1730–36 — Pretended distinction between ancient and modern lavas — Recent oolitic travertin in Lancerote — Submarine volcanos (p. 198.) — Graham Island formed in 1831 — Von Buch's Theory of "Elevation Craters" considered (p. 205.) — Santorin and its contiguous isles — Isle of Palma, a supposed "Crater of Elevation" (p. 213.) — Barren Island in the Bay of Bengal — Mineral composition of volcanic products (p. 223.) — Speculations respecting igneous rocks produced at great depths by modern volcanic eruptions.

Volcanic archipelagos. — In our chronological sketch of the changes which have happened within the traditionary and historical period in the volcanic district round Naples, we described the renewal of the fires of a central and habitual crater, and the almost entire cessation of a series of irregular eruptions from minor and independent vents. Some volcanic archipelagos offer interesting examples of the converse of this phenomenon; the great habitual vent having become almost sealed up, and eruptions of great violence now proceeding, either from different points in the bed of the ocean, or from adjoining islands, where, as formerly in Ischia, new cones and craters are formed from time to time. Of this state of things the Canary Islands now afford an example.

Peak of Teneriffe.—The highest crater of the Peak of Teneriffe has been in the state of a solfatara ever since it has been known to Europeans; but several

eruptions have taken place from the sides of the mountain; one in the year 1430, which formed a small hill, and another in 1704 and the two following years, accompanied with great earthquakes, when the lava overflowed a town and harbour. Another eruption happened in June, 1798, not far from the summit of the peak. But these lateral emissions of lava, at distant intervals, may be considered as of a subordinate kind, and subsidiary to the great discharge which has taken place in the contiguous isles of Palma and Lancerote; and the occasional activity of the peak may be compared to the irregular eruptions before mentioned, of the Solfatara, of Arso in Ischia, and of Monte Nuovo, which have broken out since the renewal of the Vesuvian fires in 79.

Eruption in Lancerote, 1730 *to* 1736.—The effects of one of these insular eruptions in the Canaries, which happened in Lancerote, between the years 1730 and 1736, were very remarkable; and a detailed description has been published by Von Buch, who had an opportunity, when he visited that island in 1815, of comparing the accounts transmitted to us of the event, with the present state and geological appearances of the country.* On the 1st of September, 1730, the earth split open on a sudden two leagues from Yaira. In one night a considerable hill of ejected matter was thrown up; and a few days later, another vent opened, and gave out a lava-stream, which overran Chinanfaya and other villages. It flowed first rapidly, like water, but became afterwards

* This account was principally derived by Von Buch from the MS. of Don Andrea Lorenzo Curbeto, Curate of Yaira, the point where the eruption began.— Ueber einen vulcanischen Ausbruch auf der Insel Lanzerote.

heavy and slow, like honey. On the 7th of September an immense rock was protruded from the bottom of the lava, with a noise like thunder, and the stream was forced to change its course from N. to N. W., so that St. Catalina and other villages were overflowed.

Whether this mass was protruded by an earthquake, or was a mass of ancient lava, blown up like that before mentioned in 1783 in Iceland, is not explained.

On the 11th of September more lava flowed out, and covered the village of Maso entirely, and, for the space of eight days, precipitated itself with a horrible roar into the sea. Dead fish floated on the waters in indescribable multitudes, or were thrown dying on the shore. After a brief interval of repose, three new openings broke forth immediately from the site of the consumed St. Catalina, and sent out an enormous quantity of lapilli, sand, and ashes. On the 28th of October, the cattle throughout the whole country dropped lifeless to the ground, suffocated by putrid vapours, which condensed and fell down in drops. On the 1st of December a lava stream reached the sea, and formed an island, round which dead fish were strewed.

Number of cones thrown up.—It is unnecessary here to give the details of the overwhelming of other places by fiery torrents, or of a storm which was equally new and terrifying to the inhabitants, as they had never known one in their country before. On the 10th of January, 1731, a high hill was thrown up, which, on the same day, precipitated itself back again into its own crater; fiery brooks of lava flowed from it to the sea. On the 3rd of February a new cone arose. Others were thrown up in March, and poured forth lava-streams. Numerous other volcanic cones were

subsequently formed in succession, till at last their number amounted to about thirty. In June, 1731, during a renewal of the eruptions, all the banks and shores in the western part of the island were covered with dying fish, of different species, some of which had never before been seen. Smoke and flame arose from the sea, with loud detonations. These dreadful commotions lasted without interruption for *five successive years*, so that a great emigration of the inhabitants became necessary.

Their linear direction.—As to the height of the new cones, Von Buch was assured that the formerly great and flourishing St. Catalina lay buried under hills 400 feet in height; and he observes that the most elevated cone of the series rose 600 feet above its base, and 1378 feet above the sea, and that several others were nearly as high. The new vents were all arranged *in one line*, about two geographical miles long, and in a direction nearly east and west. If we admit the probability of Von Buch's conjecture, that these vents opened along the line of a cleft, it seems necessary to suppose that this subterranean fissure was only prolonged upwards to the surface by degrees, and that the rent was narrow at first, as is usually the case with fissures caused by earthquakes. Lava and elastic fluids might escape from some point on the rent where there was least resistance, till, the first aperture becoming obstructed by ejections and the consolidation of lava, other orifices burst open in succession, along the line of the original fissure. Von Buch found that each crater was lowest on that side on which lava had issued; but some craters were not breached, and were without any lava-streams. In one of these were open fissures, out of which hot vapours rose, which in 1815

raised the thermometer to 145° Fahrenheit, and was probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour; yet they could not be pure steam, for the crevices were encrusted on either side by siliceous sinter (an opal-like hydrate of silica of a white colour), which extended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and how open fissures may be filled up laterally by mineral matter, sublimed from volcanic exhalations. The lavas of this eruption covered nearly a third of the whole island, often forming on slightly inclined planes great horizontal sheets several square leagues in area, resembling very much the basaltic plateaus of Auvergne.

Pretended distinction between ancient and modern lavas.—One of the new lavas was observed to contain masses of olivine of an olive-green colour, resembling those which occur in one of the lavas of the Vivarais. Von Buch supposes the great crystals of olivine to have been derived from a previously existing basalt melted up by the new volcanos; but he gives no sufficient data to bear out such a conjecture. The older rocks of the island consist, in a great measure, of that kind of basaltic lava called dolerite, sometimes columnar, and partly of common basalt and amygdaloid. Some recent lavas assumed, on entering the sea, a prismatic form, and so much resembled the older lavas of the Canaries, that the only geological distinction which Von Buch appears to have been able to draw between them was, that they did not alternate with conglomerates, like the ancient basalts. Some modern writers have endeavoured to discover, in the abundance

of these conglomerates, a proof of the dissimilarity of the volcanic action in ancient and modern times; but this character is more probably attributable to the difference between submarine operations and those on the land. All the blocks and imperfectly rounded fragments of lava, transported, during the intervals of eruption, by rivers and torrents, into the adjoining sea, or torn by the continued action of the waves from cliffs which are undermined, must accumulate in stratified breccias and conglomerates, and be covered again and again by other lavas. This is now taking place on the shores of Sicily, between Catania and Trezza, where the sea breaks down and covers the shore with blocks and pebbles of the modern lavas of Etna; and on parts of the coast of Ischia, where numerous currents of trachyte are in like manner undermined in lofty precipices. So often then as an island is raised in a volcanic archipelago by earthquakes from the deep, the fundamental and (relatively to all above) the oldest lavas will often be distinguishable from those formed by subsequent eruptions on dry land, by their alternation with beds of sandstone and fragmentary rocks.

The supposed want of identity then between the volcanic phenomena of different epochs resolves itself into the marked difference between the operations simultaneously in progress, above and below the waters. Such, indeed, is the source, as was before stated in the First Book (Chap. V.), of many of our strongest theoretical prejudices in geology. No sooner do we study and endeavour to explain submarine appearances, than we feel, to use a common expression, out of our element; and, unwilling to concede that our

extreme ignorance of processes now continually going on can be the cause of our perplexity, we take refuge in a "pre-existent order of nature."

Recent formation of oolitic travertin in Lancerote. — Throughout a considerable part of Lancerote, the old lavas are covered by a thin stratum of limestone, from an inch to two feet in thickness. It is of a hard stalactitic nature, sometimes oolitic, like the Jura limestone, and contains fragments of lava and terrestrial shells, chiefly helices and spiral bulimi. Von Buch imagines, that this remarkable superstratum has been produced by the furious north-west storms, which in winter drive the spray of the sea in clouds over the whole island; from whence calcareous particles may be deposited stalactitically. If this explanation be correct, and it seems highly probable, the fact is interesting, as attesting the quantity of matter held in solution by the sea-water, and ready to precipitate itself in the form of solid rock. At the bottom of such a sea, impregnated, as in the neighbourhood of all active volcanos, with mineral matter in solution, lavas must be converted into calcareous amygdaloids, a form in which the igneous rocks so frequently appear in the older European formations. I may mention that recent crevices in the rocks of Trezza, one of the Cyclopian isles at the foot of Etna, are filled with a kind of travertin, as high as the spray of the sea reaches; and included in this hard veinstone I have seen fragments, and even entire specimens, of recent shells thrown up by the waves.

Recent eruption in Lancerote. — From the year 1736 to 1815, when Von Buch visited Lancerote, there had been no eruption; but, in August, 1824, a crater

opened near the port of Rescif, and formed, by its ejections, in the space of twenty-four hours, a considerable hill. Violent earthquakes preceded and accompanied this eruption.*

Submarine volcanos. — Although we have every reason to believe that volcanic eruptions as well as earthquakes are common in the bed of the sea, it was not to be expected that many opportunities would occur to scientific observers of witnessing the phenomena. The crews of vessels have sometimes reported that they have seen in different places sulphureous smoke, flame, jets of water, and steam, rising up from the sea, or they have observed the waters greatly discoloured, and in a state of violent agitation as if boiling. New shoals have also been encountered, or a reef of rocks just emerging above the surface, where previously there was always supposed to have been deep water. On some few occasions the gradual formation of an island by a submarine eruption has been observed, as that of Sabrina, in the year 1811, off St. Michael's, in the Azores. The throwing up of ashes in that case, and the formation of a cone about three hundred feet in height, with a crater in the centre, closely resembled the phenomena usually accompanying a volcanic eruption on land. Sabrina was soon washed away by the waves. Previous eruptions in the same part of the sea were recorded to have happened in 1691 and 1720. The rise of Nyöe, also, a small island off the coast of Iceland, in 1783, has

* Férussac, Bulletin des Sci. Nat., tome v. p. 45. 1825. The volcano was still burning when the account here cited was written.

already been alluded to, and another volcanic isle was produced by an eruption near Reikiavig, on the same coast, in June, 1830.*

Graham Island†, 1831.—We have still more recent and minute information respecting the appearance, in 1831, of a new volcanic island in the Mediterranean, between the S. W. coast of Sicily and that projecting part of the African coast where ancient Carthage stood. The site of the island was not any part of the great shoal, or bank, called "Nerita," as was first asserted, but a spot where Captain W. H. Smyth had found, in his survey a few years before, a depth of more than one hundred fathoms' water.‡

The position of the island (lat. 37° 8′ 30″ N., long. 12° 42′ 15″ E.) was about thirty miles S.W. of Sciacca in Sicily, and thirty-three miles N.E. of Pantellaria.§ On the 28th of June, about a fortnight before the eruption was visible, Sir Pulteney Malcolm, in passing over the spot in his ship, felt the shocks of an earthquake, as if he had struck on a sand-bank; and the same shocks were felt on the west coast of Sicily, in a direction from S.W. to N.E. About the 10th of July, John Corrao, the captain of a Sicilian vessel,

* Journ. de Géol., tome i.

† In a former edition, I selected the name of Sciacca out of seven which had been proposed; but the Royal and Geographical Societies have now adopted Graham Island; a name given by Captain Senhouse, R. N., the first who succeeded in landing on it. The seven rival names are, Nerita, Ferdinanda, Hotham, Graham, Corrao, Sciacca, Julia. As the isle was visible for only about three months, this is an instance of a wanton multiplication of synonyms which has scarcely ever been outdone even in the annals of zoology and botany.

‡ Phil. Trans. 1832, p. 255.

§ Journ. of Roy. Geograph. Soc. 1830-31.

reported that, as he passed near the place, he saw a column of water like a water-spout, sixty feet high, and eight hundred yards in circumference, rising from the sea, and soon afterwards a dense steam in its place, which ascended to the height of 1800 feet. The same Corrao, on his return from Gergenti, on the 18th of July, found a small island, twelve feet high, with a crater in its centre, ejecting volcanic matter, and immense columns of vapour; the sea around being covered with floating cinders and dead fish. The scoriæ were of a chocolate colour, and the water which boiled in the circular basin was of a dingy red. The eruption continued with great violence to the end of the same month; at which time the island was visited by several persons, and, among others, by Captain Swinburne, R. N., and M. Hoffmann, the Prussian geologist. It was then from fifty to ninety feet in height, and three quarters of a mile in circumference. By the 4th of August it became, according

Fig. 22.

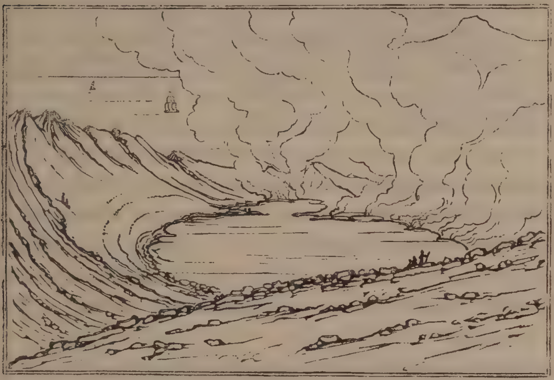
Form of the cliffs of Graham Island, as seen from S. S. E., distant one mile, 7th August, 1831. *

to some accounts, above 200 feet high, and three miles in circumference; after which it began to diminish in size by the action of the waves, and was only two

* Phil. Trans., part ii., 1832, reduced from drawings by Captain Wodehouse, R. N.

miles round on the 25th of August; and on the 3d of September, when it was carefully examined by Captain Wodehouse, only three-fifths of a mile in circumference, its greatest height being then 107 feet. At this time the crater was about 780 feet in circumference. On the 29th of September, when it was visited by Mons. C. Prevost, its circumference was reduced to about seven hundred yards. It was com-

Fig. 23.



View of the interior of Graham Island, 29th Sept. 1831.

posed entirely of incoherent ejected matter, scoriæ, pumice, lapilli, and cinders, forming regular strata, some of which are described as having been parallel to the steep inward slope of the crater, while the rest were inclined outwards, like those of Vesuvius. In the annexed sketch, however (fig. 24.), drawn by M. Joinville, who accompanied M. C. Prevost, all the beds are represented as sloping towards the axis of the crater; and, if the view be correct, we must suppose that the last remnant only of the cone was then preserved, namely, that central part where the beds

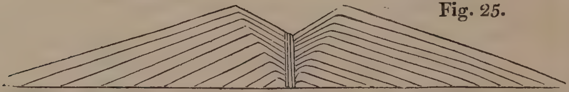
have all an inward dip.* When the arrangement of the

Fig. 24.

Graham Island, 29th Sept. 1831.

ejected materials has been determined by their falling continually on two steep slopes, that of the external cone and that of the crater, which is always a hollow inverted cone, a transverse section would probably resemble that given in the annexed figure (25.) But

Fig. 25.



when I visited Vesuvius, in 1828, I saw no beds of scoriæ inclined towards the axis of the cone (see fig. 20. p. 139.) Such may have existed; but the explosions, or subsidences, or whatever causes produced the great crater of 1822, had possibly destroyed them.

Few of the pieces of stone thrown out from Graham Island exceeded a foot in diameter. Some fragments of dolomitic limestone were intermixed; but these were the only non-volcanic substances. During the

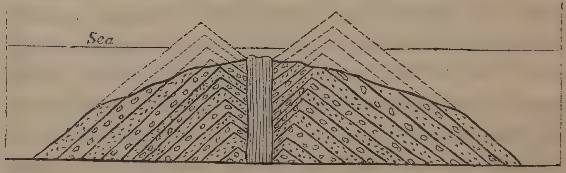
* See memoir by M. C. Prevost, Ann. des Sci. Nat., tom. xxiv.

month of August, there occurred on the S. W. side of the new island a violent ebullition and agitation of the sea, accompanied by the constant ascension of a column of dense white steam, indicating the existence of a second vent at no great depth from the surface. Towards the close of October, no vestige of the crater remained, and the island was nearly levelled with the surface of the ocean, with the exception, at one point, of a small monticule of sand and scoriæ. It was reported that, at the commencement of the year following (1832), there was a depth of 150 feet where the island had been: but this account was quite erroneous; for in the early part of that year Captain Swinburne found a shoal and discoloured water there, and towards the end of 1833 a dangerous reef existed, of an oval figure, about three fifths of a mile in extent. In the centre was a black rock, of the diameter of about twenty-six fathoms, from nine to eleven feet under water; and round this rock are banks of black volcanic stones and loose sand. At the distance of sixty fathoms from this central mass, the depth increased rapidly. There was also a second shoal at the distance of 450 feet S. W. of the great reef, with fifteen feet water over it, also composed of rock surrounded by deep sea. We can scarcely doubt that the rock in the middle of the larger reef is solid lava which rose up in the principal crater, and that the second shoal marks the site of the submarine eruption observed in August, 1831, to the S. W. of the island.

From the whole of the facts above detailed, it appears that a hill eight hundred feet or more in height was formed by a submarine volcanic vent, of which the upper part (only about two hundred feet high) emerged

above the waters, so as to form an island. This cone must have been equal in size to one of the largest of the lateral volcanos on the flanks of Etna, and about half the height of the mountain Jorullo in Mexico, which was formed in the course of nine months, in 1759. In the centre of the new volcano a large cavity was kept open by gaseous discharges, which threw out scoriæ; and fluid lava probably rose up in this cavity. It is not uncommon for small subsidiary craters to open near the summit of a cone, and one of these may have been formed in the case of Graham Island; a vent, perhaps, connected with the main channel of discharge which gave passage in that direction to elastic fluids, scoriæ, and melted lava. It does not appear that, either from this duct, or from the principal vent, there was any overflowing of lava; but melted rock may have flowed from the flanks or base of the cone (a common occurrence on land), and may have spread in a broad sheet over the bottom of the sea.

Fig. 26.



The dotted lines in the annexed figure are an imaginary restoration of the upper part of the cone, now removed by the waves: the strong lines represent the part of the volcano which is still under water. In the centre is a great column, or dike, of solid lava, two hundred feet in diameter, supposed to fill the space by

which the gaseous fluids rose; and on each side of the dike is a stratified mass of scoriæ and fragmentary lava. The solid nucleus of the reef where the black rock is now found withstands the movements of the sea; while the surrounding loose tuffs are cut away to a somewhat lower level. In this manner the lava, which was the lowest part of the island, or to speak more correctly, which scarcely ever rose above the level of the sea when the island existed, has now become the highest point in the reef.

No appearances observed, either during the eruption or since the island disappeared, give the least support to the opinion promulgated by some writers, that part of the ancient bed of the sea had been lifted up bodily.

The solid products, says Dr. John Davy, whether they consisted of sand, light cinders, or vesicular lava, differed more in form than in composition. The lava contained augite; and the specific gravity was 2·07 and 2·70. When the light spongy cinder, which floated on the sea, was reduced to fine powder by trituration, and the greater part of the entangled air got rid of, it was found to be of the specific gravity 2·64; and that of some of the sand which fell in the eruption was 2·75*; so that the materials equalled ordinary granites in weight and solidity. The only gas evolved in any considerable quantity was carbonic acid.†

Theory of Elevation Craters.‡ — Before quitting the subject of submarine volcanos, it will be necessary to

* Phil. Trans. 1832, p. 243. † Ibid. 249.

‡ The view which I now give of the theory of elevation craters is the same which I published in the first edition, printed in 1829, after I had examined Vesuvius and Etna, and compared them with the Mont Dor and the Plomb du Cantal. But I have now incorporated with the illustrations and arguments then advanced, some

say something of an opinion which has been promulgated by Leopold Von Buch, respecting what he has termed Erhebungs crater (Cratères de Soulèvement). He has attempted to explain, by a novel hypothesis, the origin of certain large cavities, and the peculiar disposition of the masses of volcanic matter which surround them. We shall first consider the island of Santorin in the Grecian archipelago,—one of the examples of this mode of formation instanced by Von Buch.

The three islands of Santorin, Therasia, and Aspronisi surround an almost circular gulf of about two leagues in diameter from south to north, and a league and a half from east to west. The island of Santorin itself forms more than two thirds of the circuit, and is composed entirely of volcanic matter, with the exception of its southern part, which rises to three times the height of the igneous rocks in the island, and is formed of granular limestone and argillaceous schist.* This mountainous part is the original and fundamental nucleus of the isle; and, according to M. Bory de St. Vincent, its strata have the same direction as those of the other isles of the Grecian archipelago, from N.N.W.

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information derived from the subsequent observations of M. Virlet and others. Neither that gentleman, in his memoir cited below, nor M. Hoffmann, in his letter on the subject addressed to the Geological Society of France, nor M. Cordier, in his paper on the Cantal, have referred to my previous sketch of the controversy, and were, probably, not aware of what Mr. Scrope and myself had written on the subject; but it is satisfactory and important to observe, that they have followed the same line of argument and illustration.

* Virlet. Bull. de la Soc. Géol. de France, tom. iii. p. 103.

to S.S.E. Their inclination and fractures have no relation to the position of the newer volcanic rocks, of

Fig. 27.

Chart and section of Santorin and the contiguous islands in the Grecian Archipelago.

which the remainder of the group of islands is exclusively composed. The volcanic mass, which must be considered as quite an independent formation, consists of alternating beds of trachytic lava, tuff, and conglomerate, which dip on every side from the centre of the gulf to the circumference. Towards the gulf they present uniformly a high and steep escarpment, the precipices in Santorin rising to the height of more than eight hundred feet, and plunging at once into a sea

from eight hundred to a thousand feet deep. Each of the islands is capped by an enormous mass of white tufaceous conglomerate, from forty to fifty feet in thickness; which is not pumice, as has often been stated. The beds of lava and tuff, above mentioned, are accumulated in great numbers one upon another, and of unequal thickness: although disposed with great regularity, when viewed as a whole, they are found to be discontinuous, as in Vesuvius, when any particular mass is traced to some distance.

Before discussing the merits of the theory proposed to account for the structure of this volcanic group, it will be desirable to give a brief sketch of its history, so far as it is known. Pliny relates that the separation of Therasia from Thera, or Santorin, took place after a violent earthquake, in the year 233 before the Christian era. From his work, and other authorities, we also learn that the year 196 B.C. gave birth, in the middle of the gulf, to Hiera, or the Sacred Isle, still called Hiera-Nisos, or sometimes Palaia Kameni (Old Burnt Island). There seems to have been no eruption then, but simply an upheaving of solid lava. In the year 19 of our era, Thia (the Divine) made its appearance above the surface of the waters. This small island has no longer a separate existence, having been joined to Hiera, from which it was only 250 paces distant: Hiera itself increased in size in 726 and in 1427. In 1573, the small island of Micra-Kameni appeared, a small cone and crater, one hundred feet high, raised by successive ejections.

On the 27th of September, 1650, there was an eruption three or four miles north of Santorin, altogether outside of the gulf, immediately after violent earthquakes. It gave rise to no new islet, but greatly

elevated the bottom of the sea on the spot. The eruption lasted three months: many houses on Santorin were destroyed; and the vapours of sulphur and hydrogen killed more than fifty persons, and more than one thousand domesticated animals. A wave fifty feet high broke upon the rocks of the Isle of Nio, about four leagues distant, and advanced 350 yards into the interior of the island of Sikino, which is seven leagues off. The sea also broke upon Santorin, overthrew two churches, and exposed to view a village on each side of the mountain of St. Stephen, both of which must have been overwhelmed by showers of volcanic matter during some former eruption.*

Lastly, in 1707 and 1709, Nea Kameni was produced between Palaia and Micra (old and lesser) Kamenis. This isle was composed originally of two distinct parts, the first which rose was called the White Island — a mass of pumice, extremely porous. Goree the Jesuit, who was then in Santorin, says that the rock "cut like bread," and that, when the inhabitants landed on it, they found a multitude of full-grown fresh oysters adhering to it, which they eat.† This island was afterwards covered, in great part, by the matter ejected from the crater of the second island, produced at the same time, called "Black Island," being composed partly of brown trachyte. This volcano, now named Nea (or New) Kameni, continued in eruption, at intervals, during 1711 and 1712, and formed a cone 330 feet above the level of the sea: there are now, therefore, two channels of direct communication

* Virlet, Bull. de la Soc. Géol. de France, tom. iii. p. 103.

† Phil. Trans., No. 332.

between the atmosphere and volcanic foci beneath the group of Santorin; namely, the craters of New and Little Kameni.

A curious fact is mentioned by M. Virlet, respecting the supposed slow and progressive rise of a solid ridge at the bottom of the sea. Twenty years ago there was a depth of fifteen fathom water between the lesser Kameni and the port of Phira in Santorin. In 1830, when MM. Virlet and Bory visited the spot, there was only a depth of between three and four fathoms; and they found that the bottom consisted of a hard rock, probably trachyte, measuring about eight hundred yards from E. to W. and five hundred only from N. to S. Beyond this the sea deepens rapidly on all sides. From these facts, and from information obtained on the spot, M. Virlet infers that the bed of the sea is rising gradually, and that, in all probability, a new island may one day appear without commotion above the surface. He suggests that the solid crust of rock now slowly rising may resemble a cork carried up by the fermentation of the liquor on which it floats.*

After the explanation which I before offered† of the mode in which the semicircular escarpment of Somma must have originated, it is almost needless to say that I regard the three islands which encircle the gulf of Santorin as nothing more than the ruins of a great volcanic cone, the summit of which, like that of the ancient Vesuvius, has been destroyed; and as to the small volcanic islets thrown up since the historical era, in the centre of the gulf, they may be compared

* See M. Virlet's Memoir, before cited.

† Above, p. 139.

to the modern cone, or rather cones, of Vesuvius. But Von Buch's hypothesis suggests a very different origin for Santorin, and other islands and gulfs of a similar configuration. He supposes that the different masses of tuff, conglomerate, and whatever else may be associated, were first horizontally disposed along the floor of the ocean. An expansive force from below then burst an opening through them, and, acting from a central point, raised symmetrically on every side whatever resisted its action; so that the uplifted strata were made to dip on all sides from the centre, as is usual in volcanic cones; while a deep hollow was left in the middle, resembling in all essential particulars an ordinary volcanic crater.

It was never pretended that this theory was founded on the actual observation, in any part of the globe, of analogous effects produced by the elevating force of earthquakes, or the escape of elastic fluids; for the inflation, from below, of the rocks in the plain of Malpais, during the eruption of Jorullo, was, as before stated, an hypothesis proposed, long after that eruption, to account for appearances which admit of a different explanation. Besides, in that case, there was no great hollow formed in the centre of the whole mass of lava, although there is an eruption-crater on the summit of Jorullo itself.

It is naturally objected by M. Virlet, that if a mass like Santorin, which, including its submarine foundations, must be from 1700 to 2000 feet in thickness, was suddenly and violently heaved up from a horizontal position, we might expect to find the rocks furrowed every where with rents which would diverge from the principal centre of movement to the circumference of

the circular area. But these rents are wanting, as are all signs of the shattering and dislocation of the mass. At the same time he adduces a fact which must surely prove conclusive against the notion of the island's having been formed in any other mode than that by which an ordinary cone is accumulated. In examining the various currents of lava (the existence of which was unknown to Von Buch, who had not visited Santorin), it was found that the vesicles, or pores which abound in them, are lengthened in the several directions in which they would naturally be drawn out, if the melted matter had flowed towards different points of the compass from the summit of a conical mountain, of which the present islands were the base. The force of this argument will be appreciated by those who are aware that bubbles of confined gas in a fluid in motion assume an oval form, and that the direction of the longer axis coincides always with that of the stream. It is also observed by M. Virlet, that the deep stratum of white tufaceous conglomerate by which all the islands are uniformly covered, may well be supposed to have resulted from heavy showers of ejected matter which fell during that paroxysmal explosion by which the great cone was originally blown up, truncated, and emptied in its interior.

The manner in which the external walls were separated into three distinct islands is easily conceived. The principal breaches are to the N. W., the quarter most exposed to the waves and currents. On this side, the earthquake of 233 B.C., mentioned by Pliny, may have caused a fissure, which allowed the waves and currents to penetrate and sweep away the incoherent tuffs and conglomerates, just as they washed

away Graham Island; and if there happened to be little or no lava at certain points, the waves would in such places readily force a passage.*

Isle of Palma. — The next example which may claim our attention is Palma, one of the Canary Islands; and, when controverting Von Buch's theoretical opinions, we must not forget how much geology is indebted to his talents and zeal for his faithful description of this interesting group of islands.

In the centre of Palma is an immense circular cavity, called the Caldera, which forms the hollow axis of the entire island. A lofty mountain ridge runs

Fig. 28.

View of the Isle of Palma, and of the Caldera in its centre.

round this axis, and presents in all directions, towards the Caldera, a perpendicular precipice of no less than four thousand feet in height: while on the outside the slope is gentle towards the sea. The middle of the Caldera is more than two thousand feet above the level of the ocean; the surrounding borders (or "cumbre," as they are termed,) are of various heights, attaining at one point an elevation of 7234 feet. The diameter of the Caldera is about six miles;

* Virlet, ibid.

and so steep are the cliffs by which it is environed, that there is not a single pathway down the rocks; and the only entrance is by the ravine, or "baranco," which runs from the great circus down to the sea, intersecting all the rocks of which the island is composed. In this section are exposed strata of tuff, alternating with beds of basalt; and below are conglomerates, composed of fragments of granite, quartz, syenite, and other hypogene rocks, some of which appear in one place in situ. Volcanic dikes, or veins, cutting through all these formations, increase in number as the traveller passes through the baranco, or gorge, and, receding farther from the sea, approaches nearer to the Caldera. The veins in the precipice on each side often cross one another, and at length form a perfect net-work. In the cliffs encircling the Caldera itself are various volcanic rocks, traversed by basaltic dikes, most of which are perpendicular, and appear to hold together the more incoherent masses through which they cut. The sloping sides of the island, which has much the appearance of a flattened and hollow cone, are furrowed by numerous minor ravines, deepening as they approach the sea, in which beds of red and yellow scoriæ are exposed to view.

From this description I find it impossible to draw any other inference than that we have here the remains of a great volcanic mountain, formed by successive eruptions, the first of which burst through granitic rocks. A great cone having, in the course of ages, been built up, the higher parts of it were afterwards destroyed, and an immense hollow occasioned by gaseous explosions; at the same time that a falling in, or engulphment, of large masses may have taken place. But, according to the theory of "erhebungs crater," we

are called upon to suppose, that a series of horizontal beds of volcanic matter were first accumulated over each other, to the enormous depth of more than four thousand feet, — an hypothesis which alone implies the proximity of a vent, from which immense quantities of igneous rocks had proceeded: next, that, after the aggregation of the mass, the expansive force was directed on a given point with such extraordinary energy, as to lift up bodily the whole mass, so that it should rise in some parts to the height of seven thousand feet above the sea, leaving a great gulf or cavity in the middle. Yet, notwithstanding this prodigious effort of gaseous explosions, concentrated on so small a point, the beds, instead of being shattered, contorted, and thrown into the utmost disorder, have acquired that regular and symmetrical arrangement which characterize the flanks of a large cone of eruption like Etna! It will readily be admitted, that earthquakes, when they act on extensive tracts of country, may elevate and depress them without deranging considerably the relative position of hills, valleys, and ravines. But if the aeriform fluids should break through a mere point, as it were, of the earth's crust, and that, too, where the beds were not composed of soft yielding clay, or incoherent sand, but in great part of solid trachyte and basalt, thousands of feet thick, is it possible to conceive that such masses of rock could be heaved up, so as to attain the height of seven thousand feet, or more, without being thrown into a vertical, and often into a reversed position? Would they not be fissured and fractured in every direction, and, instead of forming a mountain of regular form and structure, would they not be reduced to a mere confused and chaotic heap?

The dimensions of the Gulf of Santorin, or the Caldera of the Isle of Palma, are not greater than we may suppose to result from the truncation and evacuation of ordinary volcanic cones. We shall afterwards see that Papandayang, formerly one of the loftiest volcanos in Java, lost, in 1772, about four thousand feet of its former height.* During an eruption in 1444, accompanied by a tremendous earthquake, the summit of Etna was destroyed, and an enormous crater was left, from which lava flowed. The segment of that crater may still be seen near the Casa Inglese, and, when complete, it must have measured several miles in diameter. The cone was afterwards repaired; but this might not so easily have happened, had the summit of Etna, like Stromboli or Santorin, been placed in a deep sea; for in that case the vent might have become choked up with strata of sand and conglomerate, swept in by waves and currents; and these obstructions, by augmenting the repressive force, would have increased the violence of subsequent explosions. There is, unquestionably, a much greater probability when the volcanic vent communicates with the atmosphere that a channel will be kept open by elastic fluids, whereby currents of lava may escape without resistance, and without causing any violent commotion. Let us suppose the large Etnean crater of 1444 to have been choked up, and again truncated down to the upper margin of the woody region; a circular basin would thus have been formed, thirty Italian miles in circumference, exceeding by five or six miles the circuit of the Gulf of Santorin. Yet we know, by numerous sections, that the strata of

* See chap. xvi.

trachyte, basalt, and trachytic breccia, would, in that part of the great cone of Etna, dip on all sides off from the centre, at a gentle angle, to every point of the compass, except where irregularities were occasioned, at certain points, by the occurrence of the small buried cones before mentioned. If this gulf were, then, again choked up, and the vent obstructed, so that new explosions of great violence should truncate the cone once more down to the inferior border of the forest zone of Etna, the circumference of the gulf would be fifty Italian miles.* Yet even then the ruins of the cone of Etna might form a circular island, entirely composed of volcanic rocks, sloping gently outwards on all sides, at a very slight angle; and this island might be between seventy and eighty English miles in its exterior circuit, rivalling Palma in fertility; while the circular bay within might be between forty and fifty miles round.

If a difference in size alone were a sufficient reason for seeking a difference in origin, we should then be called upon to refer the innermost cone of Vesuvius, thrown up in 1828, to a mode of action distinct from that by which the larger cone of the year 79 was formed; and the shape and structure of this, again, might be attributed to a series of operations distinct from those to which the outermost cone and escarpment of Somma were due. It is extraordinary that, after the identity of the form and structure of Vesuvius and Somma had been so clearly demonstrated by M. Necker †, one of these cones should actually have

* For the measurements of different parts of the cone of Etna, see Trattato dei Boschi del' Etna, Scuderi, Acti dell' Acad. Gion. de Catan., vol. i.

† Mémoire sur le Mont Somma, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tom. ii. part i. p. 155.

been considered by some of the followers of Von Buch as an "erhebungs crater," and the other as a cone of eruption. (See fig. 20. p. 139.)

Great Canary. — The form of the Great Canary is very analogous to that of Palma, there being here also a caldera and a principal ravine leading out of it, on the south side. The rocks are tuff, conglomerate, basalt, and trachyte. In some of the borders of the island are marls and conglomerates containing *recent* marine shells, from three to four hundred feet above the level of the sea, and presenting an appearance, says Von Buch, as if the level of the ocean had subsided at successive periods. These are doubtless the effects of *elevation*, and at the base of Etna marine strata are in like manner discoverable; but their occurrence does not prove an upheaving of that kind, from which cones and craters would result.

Teneriffe. — The Peak of Teneriffe rises out of a valley surrounded by precipitous cliffs, which vary in height from 1000 to 1800 feet, and which are given as an exemplification of the "Erhebungs crater." The Peak stands, says Von Buch, like a tower encircled by its fosse and bastion. The volcanic rocks resemble, in general, those found in the other Canary Islands.

Barren Island.—Barren Island, in the Bay of Bengal, is also proposed as a striking illustration of the erhebungs crater; and here, it is said, we have the advantage of being able to contrast the ancient crater of elevation with a cone and crater of eruption in its centre. When seen from the ocean, this island presents, on almost all sides, a surface of bare rocks, rising, with a moderate acclivity, towards the interior; but at one point there is a cleft, by which we can penetrate into the centre, and there discover that it is

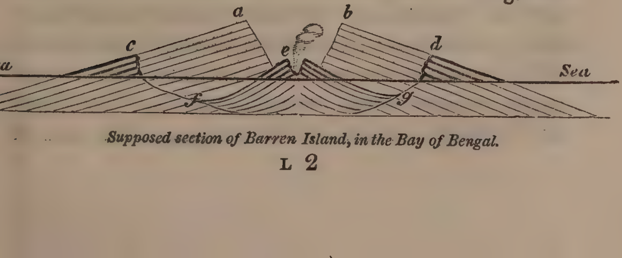
occupied by a great circular basin, filled by the waters

Fig. 29.

Cone and Crater of Barren Island, in the Bay of Bengal.

of the sea, and bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The summit of this cone is 1690 French feet in height, corresponding to that of the circular border which incloses the basin; so that it can be seen from the sea only through the ravine, which precisely resembles the deep gorge of the caldera of the Isle of Palma, and of which an equivalent, more or less decided in its characters, is said to occur in all elevation craters. It is most probable that the exterior inclosure of Barren Island, *c*, *d*, (Fig. 30.) is nothing more than the remains of a truncated cone, *c*, *a*, *b*, *d*, a great portion of which has been carried away, partly by the action of the waves, and partly by explosions which preceded the formation of the new interior cone, *f*, *e*, *g*.

Fig. 30.



Supposed section of Barren Island, in the Bay of Bengal.

Had there been any foundation for the theory, that violent explosions of gas could exert the power of raising up horizontal strata symmetrically round a central cavity, numerous examples would, ere this, have been adduced of strata *other than volcanic* elevated in this way round some active volcano. But where do we find an instance of inner craters like those of Vesuvius, Santorin, Barren Island, and others, encircled by precipices of rocks exclusively of lacustrine or marine origin, and in which the strata have the quaqua-versal dip, characteristic of all cones of eruption? If such could be pointed out, we might undoubtedly be forced to concede, that the cone and crater-like configuration may be the result of two distinct modes of formation. It is not pretended that, on the whole face of the globe, a single example of this kind can be pointed out. Are we then called upon to believe that, whenever elastic fluids generated in the subterranean regions burst through horizontal strata, so as to upheave them in the peculiar manner before adverted to, they always select, as if from choice, those spots of comparatively insignificant area where a certain quantity of volcanic matter happens to lie; while they carefully avoid purely lacustrine and marine strata, although they often lie immediately contiguous? Why, on the southern borders of the Limagne d'Auvergne, where several eruptions burst through, and elevated the horizontal marls and limestones, did these fresh-water beds never acquire, in any instance, a conical and crateriform disposition? We have no hesitation, therefore, in adhering to the opinion, that all the cavities called elevation craters by Von Buch, are simply craters of paroxysmal explosion, as they have been very properly termed by Mr. Scrope. This class of

craters, or cup-shaped hollows, have not merely been formed where the earth's crust happened to be composed of volcanic matter; but repeated explosions of elastic fluids have sometimes burst through rents in other rocks, and have shattered them for a certain space, and blown their contents into the air. Thus in the volcanic region of the Eifel, explosions, sometimes unaccompanied by the emission of lava, have excavated craters in strata of sandstone and shale; but they have not raised the strata all round the central cavity. The distinctness of these phenomena from those appealed to in corroboration of the "erhebungs crater" will be pointed out in the fourth book.

An attempt has been made to adduce the ancient volcanos of Central France, the Mont Dor, and the Plomb du Cantal, conical mountains *without craters*, or any central cavities, as illustrations of the "Erhebungs crater;" but how little their form and structure confirm this theory will be seen when they are described.* The marine shelly deposits, interstratified with basalt, through which the great cone of Etna rises, are also said to have constituted an ancient crater of elevation; but in my account of the geology of Sicily, it will appear that the strata in question do not dip so as to countenance such an hypothesis. Nor will it be difficult to show, when treating of "Valleys of Elevation," as they have been termed, that no confirmation of the views of Von Buch can be derived from the analogy of their configuration.†

Origin of the deep lateral gorge in Elevation Craters.— In regard to the deep channel of communication which appears always to connect the central cavity of the so called "Elevation Craters" with the sea, it may,

* Book iv. † Ibid.

perhaps, be ascribed, in some cases, to the action of the tides, during the gradual and successive upheaving of a volcanic isle. But to this subject I shall more particularly advert when inquiring into the causes of the configuration of coral islands.

The mountains in the moon have been pointed out, by M. Elie de Beaumont, as resembling the caldera of the isle of Palma, and other Erhebungs crater *; but an astronomer of high authority has ventured upon a very different speculation respecting these lunar mountains. "The generality of them," says Sir John Herschel, "present a striking uniformity and singularity of aspect. They are wonderfully numerous, occupying by far the larger portion of the surface, and almost universally of an exactly circular or cup-shaped form, foreshortened, however, into ellipses towards the limb; but the larger have, for the most part, flat bottoms within, from which rises centrally a small, steep, conical hill. They offer, in short, in its highest perfection, the true *volcanic* character, as it may be seen in the crater of Vesuvius, and in a map of the volcanic districts of the Campi Phlegræi, or the Puy de Dome. And in some of the principal ones, decisive marks of volcanic stratification, *arising from successive deposits of ejected matter*, may be clearly traced with powerful telescopes." †

M. Hoffmann set out on his travels through Italy and Sicily, in 1829, with a strong expectation of finding every where the clearest illustrations of the "Erhebungs crater;" but when he had explored the Lake Albano, near Rome, as well as Vesuvius, Etna, Strom-

* Ann. des Sci. Nat., Jan. 1831.

† Herschel, Treatise on Astronomy, p. 229.

boli, and the other Lipari Islands, he was compelled reluctantly to abandon the doctrine.* An examination of the same countries led M. C. Prevost, as it had done Mr. Scrope and myself, to similar conclusions.

Mineral Composition of Volcanic Products. — The mineral called felspar forms in general more than half of the mass of modern lavas. When it is in great excess, lavas are called trachytic; they consist generally of a base of compact felspar in which crystals of glassy felspar are disseminated.† When augite (or pyroxene) predominates, lavas are termed basaltic. But others of an intermediate composition occur, which from their colour have been called gray-stones. The abundance of quartz, forming distinct crystals or concretions, characterizes the granitic and other ancient rocks, now generally considered by geologists as of igneous origin: whereas that mineral is rarely exhibited in a separate form in recent lavas, although flint enters largely into their composition. Hornblende, so common in hypogene rocks, or those commonly called "primary," is rare in modern lava; nor does it enter largely into rocks of any age in which augite abounds. It should, however, be stated, that the experiments of M. Gustavus Rose have made it very questionable, whether the minerals called hornblende and augite can be separated as distinct species, as their different varieties seem to pass into each other, whether we consider the characters derived from their angles of crystallization, their chemical composition, or their specific gravity. The difference in form of the two substances may be explained by the different circumstances under which they have been produced; the

* Bulletin de la Soc. Géol. de France, tom. iii. p. 170.

† See Glossary.

form of hornblende being the result of slower cooling. Crystals of augite have been met with in the scoriæ of furnaces, but never those of hornblende; and crystals of augite have been obtained by melting hornblende in a platina crucible, but hornblende itself has not been formed artificially.* Mica occurs plentifully in some recent trachytes, but is rarely present where augite is in excess.

Frequency of eruptions, and nature of subterranean igneous rocks. — When we speak of the igneous rocks of our own times, we mean that small portion which, in violent eruptions, is forced up by elastic fluids to the surface of the earth, — the sand, scoriæ, and lava, which cool in the open air. But we cannot obtain access to that which is congealed far beneath the surface under great pressure equal to that of many hundred, or many thousand atmospheres.

During the last century, about fifty eruptions are recorded of the five European volcanic districts, of Vesuvius, Etna, Volcano, Santorin, and Iceland; but many beneath the sea in the Grecian Archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others, on the contrary, like that of Skaptár Jokul in 1783, poured out melted matter for five or six years consecutively; which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there hap-

* Bulletin de la Soc. Géol. de France, tom. ii. p. 206.

pen on the earth about two thousand eruptions in the course of a century, or about twenty every year.

However inconsiderable, therefore, may be the superficial rocks which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones must be as insignificant, when contrasted to the products of fire in the nether regions, as are the deposits formed in shallow estuaries when compared to submarine formations accumulating in the abysses of the ocean. In regard to the characters of these volcanic rocks, formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that the rocks are heavier and less porous than ordinary lavas, and more crystalline, although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages, a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions; for this is seen to be the case in many lava currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic regions; and the fissures will be often injected with similar matter, so that dikes of crystalline rock will

traverse masses of similar composition. It is also clear, that no organic remains can be included in such masses, as also that these deep-seated igneous formations considered in mass must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks either subjacent or included in the midst of them.

If, by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may then, perhaps, study in some mountain chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.

CHAPTER XIV.

EARTHQUAKES AND THEIR EFFECTS.

Earthquakes and their effects — Deficiency of ancient accounts — Ordinary atmospheric phenomena — Changes produced by earthquakes in modern times considered in chronological order — Earthquakes in Murcia, Ischia, &c. — Chili in 1822 — Extent of country elevated (p. 234.) — Aleppo and Ionian Isles — Earthquake of Cutch in 1819 — Subsidence in the delta of the Indus (p. 237.) — Island of Sumbawa in 1815 — Town of Tomboro submerged — Earthquake of Caraccas in 1812 — South Carolina in 1811 — Changes in the valley of the Mississippi (p. 246.) — Aleutian Islands in 1806 — Reflections on the earthquakes of the nineteenth century — Earthquake in Quito, Quebec, &c. — Java, 1786 — Sinking down of large tracts — Japan Isles, 1783.

In the sketch before given of the geographical boundaries of volcanic regions, I stated, that although the points of eruption are but thinly scattered, constituting mere spots on the surface of those vast districts, yet the subterranean movements extend simultaneously over immense areas. We may now proceed to consider the changes which these movements produce on the surface, and in the internal structure of the earth's crust.

Deficiency of ancient accounts.—It is only within the last century and a half, since Hooke first promulgated his views respecting the connexion between geological phenomena and earthquakes, that the per-

manent changes effected by these convulsions have excited attention. Before that time, the narrative of the historian was almost exclusively confined to the number of human beings who perished, the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulphing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical interest, to be passed over in silence. But no researches were made expressly with a view of ascertaining the amount of depression or elevation of the ground, or any particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts; and how much reason we have to regret this deficiency of information appears from this, that in every instance where a spirit of scientific inquiry has animated the eye-witnesses of these events, facts calculated to throw light on former modifications of the earth's structure are recorded.

Phenomena attending earthquakes.—As I shall confine myself almost entirely, in the following notice of earthquakes, to the changes brought about by them in the configuration of the earth's crust, I may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, that it may be unnecessary to advert to them again. Irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons,

or in countries where such phenomena are almost unknown; a reddening of the sun's disk, and a haziness in the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphureous and mephitic vapours; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder; animals uttering cries of distress, and evincing extraordinary alarm, being more sensitive than men of the slightest movement; a sensation like sea-sickness, and a dizziness in the head, experienced by men:—these, and other phenomena, which are still more remotely connected with our present subject as geologists, have recurred again and again at distant ages, and in all parts of the globe.

I shall now begin the enumeration of earthquakes with the latest authentic narratives, and so carry back the survey retrospectively, that I may bring before the reader, in the first place, the minute and circumstantial details of modern times, and thus enable him, by observing the extraordinary amount of change within the last 150 years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

EARTHQUAKES OF THE NINETEENTH CENTURY.*

Murcia, 1829.—An earthquake happened near Alicant, in the south of Spain, on the 21st of March,

* Since the publication of the former editions of this work, numerous accounts of recent earthquakes have been published; but as they do not illustrate any new principle, I cannot insert them, as they would enlarge too much the size of my work. Among the most violent may be mentioned those of Sept. 1827, at Lahore, East Indies—of Jan. 15, 1832, which destroyed Foligno, in Italy, —June 24, 1830, in China, in Tayming, North of Houan—

1829, which violently agitated a small district about four square miles in area, being the basin of the river Segura, between Orihuela and the sea. All the villages in this tract were thrown down by a vertical movement, the soil being traversed by innumerable crevices four or five inches broad. In the alluvial plain, especially that part near the sea, small circular apertures were formed, out of which black mud, salt water, and marine shells were vomited; and in other places fine, yellowish-green, micaceous sand, like that on the beach at Alicant, was thrown up in jets.*

Ischia, 1828. — On the 2d of February the whole island of Ischia was shaken by an earthquake, and in the October following I found all the houses in Casamicciol still without their roofs. On the sides of a ravine between that town and Forio, I saw masses of greenish tuff, which had been thrown down. The hot-spring of Rita, which was nearest the centre of the movement, was ascertained by M. Covelli to have increased in temperature, showing, as he observes, that the explosion took place below the reservoirs which heat the thermal waters.†

Bogota, 1827. — On the 16th of November, 1827, the plain of Bogota was convulsed by an earthquake, and a great number of towns were thrown down.

March 9, 1830, in the Caucasus at Kislier—April 1833, Manilla —1833, Isle of Lissa in Adriatic, and Opus. Von Hoff has published, from time to time, in Poggendorf's Annalen, lists of the earthquakes which have happened since 1821; and, by consulting these, the reader will perceive that every month is signalized by one or many convulsions in some part of the globe.

* Férussac, Bulletin des Sci. Nat., Nov. 1829, p. 203.

† Biblioth. Univ., Oct. 1828, p. 157.; and Férussac, Bulletin &c., tome xi. p. 297.

Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphureous vapour and destroyed the fish. Popayan, which is distant two hundred geographical miles S. S. W. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow.* It is worthy of remark, that in all such cases the ancient gravel bed of a river is deserted, and a new one formed at a lower level; so that a want of relation in the position of alluvial beds to the existing water-courses may be no test of the high antiquity of such deposits, at least in countries habitually convulsed by earthquakes. Extraordinary rains accompanied the shocks before mentioned; and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On the 19th of November, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of 1200 miles from north to south. St. Jago, Valparaiso, and some other places, were greatly injured. When the district round Valparaiso was examined on the morning after the shock, it was found that the whole line of coast, for the distance of above one hundred miles, was raised above its former level.† At Valparaiso the elevation was three feet, and at Quintero about four feet. Part of the bed of the sea, says Mrs. Graham, remained bare and dry at high water, " with

* Phil. Mag., July 1828, p. 37.

† See Geol. Trans., vol. i., second series; and also Journ. of Sci., 1824, vol. xvii. p. 40.

beds of oysters, muscles, and other shells, adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia."*

I have been informed by Mr. Cruckshanks, an English botanist, who resided in the country during the earthquake, that, for several days after the event, fishermen dug out certain burrowing shells from sands *above* low-water mark, which previously they had only procured *below* that level. The same gentleman found that some rocks of greenstone at Quintero, a few hundred yards from the beach, which had always been under water till the shock of 1822, have since been uncovered when the tide is at half-ebb; and he states that, after the earthquake, it was the general belief of the fishermen and inhabitants of the Chilian coast, that the ocean had permanently retreated, *not* that the land had risen.

An old wreck of a ship, says Mrs. Graham, which before could not be approached, became accessible from the land, although its distance from the original sea-shore had not altered.† It was observed, that the water-course of a mill, at the distance of about a mile from the sea, gained a fall of fourteen inches, in little more than one hundred yards; and from this fact it is inferred that the rise in some parts of the inland country was far more considerable than on the borders of the ocean.‡ Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a half inland. Cones of earth, about four feet high, were thrown up in several districts, by the forcing up of water mixed with sand through funnel-shaped hollows, — a pheno-

* Geol. Trans., vol. i., second series, p. 415.

† Ibid. ‡ Journ. of Sci., vol. xvii. p. 42.

menon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili of which the foundations were on rock were less damaged than such as were built on alluvial soil.

Dr. Meyen, a Prussian traveller, who visited Valparaiso in 1831, says that on examining the rocks both north and south of the town, he found appearances corroborating Mrs. Graham's statements.* According to him, the whole coast of central Chili was raised about four feet, and banks of marine shells were laid dry on many parts of the coast. He observed similar banks, elevated at unknown periods, in several places, especially at Copiapo, where the species all agree with those now living in the ocean. Mr. Fryer also, who resided some years in South America, relates, that being at Valparaiso, after the earthquake of 1822, he saw a shelly beach to the east of the town, above the reach of the tides, and rocks were pointed out to him as being now less under water than they were before the convulsion.†

On the other hand, Mr. Cuming, a gentleman well known by his numerous discoveries in conchology, and who resided at Valparaiso before the earthquake, and was there during and after the convulsion, could detect no proofs of the rise of the land, although his attention had been called to the fact by Mrs. Graham's statements. He tells me, that he had frequently collected shells from the rocks on the shore, north and south of the town, previous to and after the event, but he saw no signs of any change of level; but, on the contrary, remarked, that the water at spring tides rose after the earthquake to the same point on a wall near

* Reise um die erde.

† Geol. Soc. Proceedings, 1835.

his house, which it had reached before the shocks. He imagines that the marine shells alluded to were thrown up by the sea during the commotion, and that the idea of the coast having been raised would not have been so generally received, had there not been a rapid gain of land opposite to Valparaiso, immediately after the earthquake in 1822. This accession was caused by the continual influx of granitic sand and gravel, washed down by numerous torrents from the interior, and cast up again by the waves of the Pacific. During the nine years intervening between 1822 and 1831, the population of Valparaiso was multiplied in an extraordinary manner, and increased from 6,000 to 34,000 inhabitants; in consequence of which every effort was made to preverve the newly acquired sand-banks, and in some places no less than two entire streets have been erected where there was sea before.

I have stated these objections, trusting that they will prompt the scientific traveller and resident in Chili, to institute more minute inquiries; in the mean time I consider the testimony of the many witnesses, whose opinion was formed before any of the new additions of land had taken place, to be sufficient to establish the fact, although the change of level may perhaps be found to have been less uniform in different places than some have assumed.

Extent of country elevated.—The area over which this permanent alteration of level is conjectured to have extended is 100,000 square miles.* The whole country, from the foot of the Andes to a great distance under the sea, is supposed to have been raised, the greatest rise being at the distance of about two miles from the shore. "The rise upon the coast was from two to four feet:—at the distance of a mile

* Journ. of Sci., vol. xvii.

inland it must have been from five to six, or seven feet."* The soundings in the harbour of Valparaiso have been materially changed by this shock, and the bottom has become shallower. The shocks continued up to the end of September, 1823; even then, forty-eight hours seldom passed without one, and sometimes two or three were felt during twenty-four hours. Mrs. Graham observed, after the earthquake of 1822, that, besides the beach newly raised above high-water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea.†

In order to give some idea of the enormous amount of change which this single convulsion may have occasioned, let us assume that the extent of country moved was correctly estimated at 100,000 square miles,—an extent just equal to half the area of France, or about five-sixths of the area of Great Britain and Ireland. If we suppose the elevation to have been only three feet on an average, it will be seen that the mass of rock added to the continent of America by the movement, or, in other words, the mass previously below the level of the sea, and after the shocks permanently above it, must have contained fifty-seven cubic miles in bulk; which would be sufficient to form a conical mountain two miles high (or about as high as Etna), with a circumference at the base of nearly thirty-three miles. We may take the mean specific gravity of the rock at 2·655,—a fair average, and a convenient one

* Journ. of Sci., vol. xvii., pp. 40. 45.

† Geol. Trans., vol. i., second series, p. 415.

in such computations, because at such a rate a cubic yard weighs two tons. Then, assuming the great pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, six million tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled 100,000 pyramids.

But it must always be borne in mind that the weight of rock here alluded to constituted but an insignificant part of the whole amount which the volcanic forces had to overcome. The whole thickness of rock between the surface of Chili and the subterranean foci of volcanic action, may be many miles or leagues deep. Say that the thickness was only two miles, even then the mass which changed place and rose three feet being 200,000 cubic miles in volume, must have exceeded in weight 363 million pyramids.

It may be useful to consider these results in connection with others already obtained from a different source, and to compare the working of two antagonist forces — the levelling power of running water, and the expansive energy of subterranean heat. How long, it may be asked, would the Ganges require, according to data before explained, to transport to the sea a quantity of solid matter equal to that added to the land by the Chilian earthquake? The discharge of mud in one year by the Ganges equalled the weight of sixty pyramids. In that case it would require seventeen centuries and a half before the river could bear down from the continent into the sea a mass equal to that gained by the Chilian earthquake. In about half that number of centuries, perhaps, the united waters of the Ganges and Burrampooter might accomplish the operation.


Moultan
Indus R.
CABUL
Gurrah R.
Outch
Rohimpoor
Shikarpoor
Bukkur
Jesulmeer
Ajmeer
Sehwun
SINDE
Hyderabad
Loonee R.
Bunass R.
Delta of Indus
Mouths of the Indus
Bhooj
GOOJERAT
Cambay
G. of Cutch
Baroche
Joonaghur
Soorut
G. of Cambay
BOMBAY
Poonah


SINDE
Phurraun R.
Eastern branch of Indus
Thur Desert
Loonee R.
Boyatra
PARKUR
Nuggur
Churail
Charee
Ullah Bund
THE GRAND
Wow
Sindree
RUNN
Busta Bunder
Puchum
Khureer
Rahdinpoor
Ghorar
Bunass R.
Luckput
The Bunnee
Mhurr
CUTCH
WAGUR
RUNN OF CUTCH
Roha
BHOOJ
Anjar
Khor
Mandivee
Moondra
GULF OF CUTCH
Morevee
Jooria
Scale of British Miles
10 20 30 40 50
MAP
of the
RUNN OF CUTCH
and
LAKE OF SINDREE
By Capt. A. Burnes.

Aleppo, 1822. — *Ionian Isles*, 1820. — When Aleppo was destroyed by an earthquake in 1822, two rocks are reported to have risen from the sea near the island of Cyprus*; and a new rocky island was observed in 1820 not far from the coast of Santa Maura, one of the Ionian Islands, after violent earthquakes.†

Cutch, 1819. — A violent earthquake occurred at Cutch, in the delta of the Indus, on the 16th of June, 1819. (See map, plate 5.) The principal town, Bhooj, was converted into a heap of ruins, and its stone buildings were thrown down. The shock extended to Ahmedabad, where it was very destructive; and at Poonah, four hundred miles farther, it was feebly felt. At the former city, the great mosque erected by Sultan Ahmed nearly 450 years before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visited that point. At Anjar, the fort, with its tower and guns, were hurled to the ground in one common mass of ruin. The shocks continued some days until the 20th; when, thirty miles from Bhooj, a volcano is said to have burst out in eruption, and the convulsions ceased.

Subsidence in the Delta of the Indus. — Although the ruin of towns was great, the face of Nature in the inland country, says Captain Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. This estuary, or inlet of the sea, was, before the earthquake, fordable at Luckput, being only about

* Journ. of Sci., vol. xiv. p. 450.

† Von Hoff., vol. ii. p. 180.

a foot deep when the tide was at ebb, and at flood tide never more than six feet; but it was deepened at the fort of Luckput, after the shock, to more than *eighteen feet at low water.* * On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded one or two feet, it had become from four to ten feet deep. By these and other remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, become again practicable.

Fort and village submerged. † —The fort and village of Sindree, on the eastern arm of the Indus, above Luckput, are stated by the same writer to have been overflowed; and, after the shock, the tops of the houses and wall were alone to be seen above the water, for the houses, although submerged, were not cast down. Had they been situated, therefore, in the interior, where so many forts were levelled to the ground, their site would, perhaps, have been regarded as having remained comparatively unmoved. Hence we may suspect that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

A more recent survey of Cutch by Capt. A. Burnes, who was not in communication with Capt. Macmurdo, confirms the facts above enumerated, and adds many important details.‡ That officer examined the delta

* Macmurdo, Ed. Phil. Journ., vol. iv. p. 106.

† I am indebted to Captain Burnes for the accompanying engraving, (Pl. VI.) of the Fort of Sindree, as it appeared eleven years before the earthquake.

‡ This Memoir is now in the Library of the Royal Asiatic Society of London.

Drawn by W. Purser.

Sindree on the Eastern branch of the Indus.

SINCE SUBMERGED BY THE EARTHQUAKE OF 1819.

From a sketch taken on the spot by Capt. Grindlay in 1808.

London, Published 1834, by John Murray, Albemarle street.

of the Indus in 1826 and 1828, and from his account it appears that, when Sindree subsided in June, 1819, the sea flowed in by the eastern mouth of the Indus, and in a few hours converted a tract of land, 2000 square miles in area, into an inland sea, or lagoon. Neither the rush of the sea into this new depression, nor the movement of the earthquake, threw down entirely the small fort of Sindree, one of the four towers, the north-western, still continuing to stand; and the day after the earthquake, the inhabitants, who had ascended to the top of this tower, saved themselves in boats.*

Elevation of the Ullah Bund.—Immediately after the shock, the inhabitants of Sindree saw, at the distance of five miles and a half from their village, a long elevated mound, where previously there had been a low and perfectly level plain. (See Map, Pl. 5.) To this uplifted tract they gave the name of "Ullah Bund," or the "Mound of God," to distinguish it from several artificial dams previously thrown across the eastern arm of the Indus.

Extent of country raised.—It has been already ascertained that this new-raised country is *upwards of fifty miles* in length from east to west, running parallel to that line of subsidence before mentioned which caused the grounds around Sindree to be flooded. The range of this elevation extends from Puchum island towards Gharee; its breadth from north to south is conjectured to be in some parts *sixteen miles*, and its greatest ascertained height above the original level of the delta

* I have been enabled, from personal communication with Captain Burnes, to add several particulars to my former account of this earthquake.

is ten feet,— an elevation which appears to the eye to be very uniform throughout.

For several years after the convulsion of 1819, the course of the Indus was very unsettled, and at length, in 1826, the river threw a vast body of water into its eastern arm, that called the Phurraun, above Sinde; and forcing its way in a more direct course to the sea, burst through all the artificial dams which had been thrown across its channel, and at length cut right through the "Ullah Bund," whereby a natural section was obtained. In the perpendicular cliffs thus laid open, Captain Burnes found that the upraised lands consisted of clay filled with shells. The new channel of the river where it intersected the "bund" was eighteen feet deep, and during the swells in 1826, it was two or three hundred yards in width; but in 1828 the channel was still further enlarged. The Indus, when it first opened this new passage, threw such a body of water into the new meer, or salt lagoon, of Sindree, that it became fresh for many months; but it had recovered its saltness in 1828, when the supply of river water was less copious, and finally it became more salt than the sea, in consequence, as the natives suggested to Captain Burnes, of the saline particles with which the "Runn of Cutch" is impregnated.

In 1828 Captain Burnes went in a boat to the ruins of Sindree, where a single remaining tower was seen in the midst of a wide expanse of sea. The tops of the ruined walls still rose two or three feet above the level of the water; and standing on one of these, he could behold nothing in the horizon but water, except in one direction, where a blue streak of land to the north indicated the Ullah Bund. This scene presents to the imagination a lively picture of the revolutions

now in progress on the earth — a waste of waters where a few years before all was land, and the only land visible consisting of ground uplifted by a recent earthquake.

The Runn of Cutch, above alluded to, is a flat region of a very peculiar character, and no less than 7000 square miles in area; a greater superficial extent than Yorkshire, or about one fourth the area of Ireland. It is not a desert of moving sand, nor a marsh, but evidently the dried-up bed of an inland sea, which for a great part of every year has a hard and dry bottom uncovered by weeds or grass, and only supporting here and there a few tamarisks. But during the monsoons, when the sea runs high, the salt water driven up from the Gulf of Cutch and the creeks at Luckput overflows a large part of the Runn, especially after rains, when the soaked ground permits the sea-water to spread rapidly. The Runn is also liable to be overflowed occasionally in some parts by river-water; and it is remarkable that the only portion which was ever highly cultivated (that anciently called Sayra) is now permanently submerged. The surface of the Runn is sometimes encrusted with salt about an inch in depth, in consequence of the evaporation of the sea-water. Islands rise up in some parts of the waste, and the boundary lands form bays and promontories.

The natives have a tradition that, about three centuries ago, the countries of Cutch and Sinde were separated by the sea, thus giving rise to the district called the Runn. Towns far inland are still pointed out as having once been ancient ports; and it is said that ships were wrecked and engulphed by the great catastrophe. In confirmation of this account it was

observed, in 1819, that, in the jets of black muddy water thrown out of fissures in that region, there were cast up numerous pieces of wrought iron and ship nails.* Cones of sand six or eight feet in height are said to have been thrown up on these lands.†

We must not conclude without alluding to a *moral* phenomenon connected with this tremendous catastrophe, which we regard as highly deserving the attention of geologists. It is stated by Captain Burnes, that "these wonderful events passed *unheeded* by the inhabitants of Cutch;" for the region convulsed, though once fertile, had for a long period been reduced to sterility by want of irrigation, so that the natives were indifferent as to its fate. Now it is to this profound apathy which all but highly civilized nations feel, in regard to physical events not having an immediate influence on their worldly fortunes, that we must ascribe the extraordinary dearth of historical information concerning changes of the earth's surface, which modern observations show to be by no means of rare occurrence in the ordinary course of nature.

To the east of the line of this earthquake lies Oojain (called Ozene in the *Peryplus Maris Erythr.*). Ruins of an ancient city are there found, a mile north of the present, buried in the earth to the depth of from fifteen to sixteen feet, which inhumation is known to have been the consequence of a tremendous catastrophe in the time of the Rajah Vicramaditya.‡

Island of Sumbawa, 1815. — In April, 1815, one of

* Captain Burnes's Account.

† Captain Macmurdo's Memoir, Ed. Phil. Journ., vol. iv. p. 106.

‡ Von Hoff, vol. ii. p. 454.; for further particulars, see book 3. chap. xiv.

the most frightful eruptions recorded in history occurred in the mountain Tomboro, in the island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of 970 geographical miles in a direct line; and at Ternate, in an opposite direction, at the distance of 720 miles. Out of a population of twelve thousand, only twenty-six individuals survived on the island. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air, tore up the largest trees by the roots, and covered the whole sea with floating timber.* Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, forty miles east of the volcano, and rendered it, as well as many other dwellings in the town, uninhabitable. On the side of Java the ashes were carried to the distance of 300 miles, and 217 towards Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumatra formed, on the 12th of April, a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable pow-

* Raffles's Java, vol. i. p. 28.

der, it was of considerable weight when compressed, a pint of it weighing twelve ounces and three-quarters. Along the sea-coast of Sumbawa, and the adjacent isles, the sea rose suddenly to the height of from two to twelve feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

"On the 19th of April," says one of Raffles's correspondents, "we grounded on the bank of Bima town. The anchorage at Bima must have altered considerably, as where we grounded the Ternate cruiser lay at anchor in six fathoms a few months before." Unfortunately, no facts are stated by which we may judge with certainty whether this shoal, implying a change of depth of more than thirty feet, was caused by an accumulation of ashes, or by an upheaving of the bottom of the sea. It is stated, however, that the surrounding country was covered with ashes. On the other hand, the town called Tomboro, on the west side of the volcano, was overflowed by the sea, which encroached upon the shore at the foot of the volcano, so that the water remained permanently eighteen feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was apparent, *in spite of the ashes*, which would naturally have caused the limits of the coast to be extended.

The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca islands, Java, a considerable portion of Ce-

lebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again.*

In conclusion, I may remind the reader, that but for the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of the geologist. They mention, that similar effects, though in a less degree, had, about seven years before, accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumatra; but no particulars of that great catastrophe are recorded.†

Caraccas, 1812. — On the 26th of March, 1812, several violent shocks of an earthquake were felt in Caraccas. The surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which ten thousand of the inhabitants were buried. On the 5th of April, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from 300 to 360 feet of its height by subsidence; but this was an opinion not founded on any measurement. On the 27th of April, a volcano in St. Vincent's threw out ashes; and on the 30th, lava flowed from its crater into the sea,

* Raffles's Hist. of Java, vol. i. p. 25. — Ed. Phil. Journ., vol. iii. p. 389.

† Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo, near Valencia, as also at Porto Cabello, through openings in the earth; and in the Lake Maracaybo the water sank.*

Although the great change of level in the mountain Silla was not distinctly proved, the opinion of the inhabitants deserves attention, because I shall afterwards have to mention some well-authenticated alterations in the same district during preceding earthquakes. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.

South Carolina, 1811.—*New Madrid.*—Previous to the destruction of La Guayra and Caraccas, in 1812, South Carolina was convulsed by earthquakes; and the shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed to such a degree as to create lakes and islands. Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near the Little Prairie, became covered with water three or four feet deep; and when the water disappeared, a stratum of sand was left in its place. Large lakes of twenty miles in extent were formed in the course of an hour, and others were drained. The

* Humboldt's Pers. Nar., vol. iv. p. 12.; and Ed. Phil. Journ., vol. i. p. 272. 1819.

grave-yard at New Madrid was precipitated into the bed of the Mississippi; and it is stated that the ground whereon the town is built, and the river bank for fifteen miles above, sank eight feet below their former level.* The neighbouring forest presented for some years afterwards "a singular scene of confusion; the trees standing inclined in every direction, and many having their trunks and branches broken."†

The inhabitants relate that the earth rose in great undulations; and when these reached a certain fearful height, the soil burst, and vast volumes of water, sand, and pit-coal were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in an alluvial soil, seven years after. The people in the country, although inexperienced in such convulsions, had remarked that the chasms in the earth were in a direction from S.W. to N.E.; and they accordingly felled the tallest trees; and laying them at right angles to the chasms, stationed themselves upon them. By this invention, when chasms opened more than once under these trees several persons were prevented from being swallowed up.‡ At one period during this earthquake, the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waves. The motion of some of the shocks was horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal. If this be often the case, those shocks which injure cities least may produce the greatest alteration of level.

* Cramer's Navigator, p. 243. Pittsburgh, 1821.

† Long's Exped. to the Rocky Mountains, iii. p. 184.

‡ Silliman's Journ., Jan. 1829.

Aleutian Islands, 1806.—In the year 1806, a new island, in the form of a peak, with some low conical hills upon it, rose from the sea among the Aleutian Islands, north of Kamtschatka. According to Langsdorf*, it was four geographical miles in circumference; and Von Buch infers, from its magnitude, and from its not having again subsided below the level of the sea, that it did not consist merely of ejected matter, like Monte Nuovo, but of a solid rock of trachyte upheaved.† Another extraordinary eruption happened in the spring of the year 1814, in the sea near Unalaschka, in the same archipelago. A new isle was then produced of considerable size, and with a peak three thousand feet high, which remained standing for a year afterwards, though with somewhat diminished height.

Although it is not improbable that the earthquakes accompanying the tremendous eruptions above mentioned may have heaved up part of the bed of the sea, yet we must wait for fuller information before we assume this as a fact. The circumstance of these islands not having disappeared like Sabrina, may have arisen from the emission of lava. If Jorullo, for example, in 1759, had risen from a shallow sea to the height of 1600 feet, instead of attaining that elevation above the Mexican plateau, the massive current of basaltic lava which poured out from its crater would have enabled it to withstand, for a long period, the action of a turbulent sea.

Reflections on the Earthquakes of the nineteenth century.—We are now about to pass on to the events of

* Bemerkungen auf einer Reise um die Welt., bd. ii. s. 209.

† Neue Allgem. Geogr. Ephemer., bd. iii. s. 348.

the eighteenth century; but, before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of the last thirty years. New rocks have risen from the waters; the temperature of a thermal spring has been raised; the coast of Chili for one hundred miles has been permanently elevated; a considerable tract in the delta of the Indus has sunk down, and some of its shallow channels have become navigable; an adjoining part of the same district, upwards of fifty miles in length and sixteen in breadth, has been raised about ten feet above its former level; the town of Tomboro has been submerged, and twelve thousand of the inhabitants of Sumbawa have been destroyed. Yet, with a knowledge of these terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world, have now ceased? If, in the face of so many striking facts, he persists in maintaining this favourite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose:—

> Si fractus illabatur orbis,
> Impavidum ferient ruinæ.

EARTHQUAKES OF THE EIGHTEENTH CENTURY.

Quito, 1797.—On the morning of February 4th, 1797, the volcano of Tunguragua in Quito, and the surrounding district, for forty leagues from south to north, and twenty leagues from west to east, experienced an undulating movement, which lasted four minutes. The same shock was felt over a tract of 170 leagues from south to north, from Piura to Popayan; and 140 from west to east, from the sea to the river Napo. In the smaller district first mentioned, where the movement was more intense, every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open in several places; and streams of water and fetid mud, called "moya," poured out, overflowing and wasting every thing. In valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet; and the mud deposit barred up the course of the river, so as to form lakes, which in some places continued for more than eighty days. Flames and suffocating vapours escaped from the lake Quilotoa, and killed all the cattle on its shores. The shocks continued all February and March; and on the 5th of April they recurred with almost as much violence as at first. We are told that the form of the surface in the district most shaken was entirely altered, but no exact measurements are given whereby we may estimate the degree of elevation or subsidence.* Indeed it would be difficult, except in the immediate neigh-

* Cavanilles, Journ. de Phys., tome xlix. p. 230. Gilberts, Annalen, bd. vi. p. 67. Humboldt's Voy., p. 317.

bourhood of the sea, to obtain any certain standard of comparison, if the levels were really as much altered as the narrations imply.

Cumana, 1797. — In the same year, on the 14th of December, the small Antilles experienced subterranean movements, and four fifths of the town of Cumana was shaken down by a vertical shock. The form of the shoal of Mornerouge, at the mouth of the river Bourdones, was changed by an upheaving of the ground.*

Quebec, 1791. — We learn from Captain Bayfield's memoirs, that earthquakes are very frequent on the shore of the estuary of the St. Lawrence, of force sufficient at times to split walls and throw down chimneys. Such were the effects experienced in December, 1791, in St. Paul's Bay, about fifty miles N.E. from Quebec; and the inhabitants say, that about every twenty-five years a violent earthquake returns, which lasts forty days. In the history of Canada, it is stated that, in 1663, a tremendous convulsion lasted six months, extending from Quebec to Tadeausac, — a distance of about 130 miles. The ice on the river was broken up and many landslips caused.†

Caraccas, 1790. — In the Caraccas, near where the Caura joins the Orinoco, between the towns San Pedro de Alcantara and San Francisco de Aripao, an earthquake, on St. Matthew's day, 1790, caused a sinking in of the granitic soil, and left a lake eight hundred yards in diameter, and from eighty to one hundred in depth. It was a portion of the forest of Aripao which sub-

* Humboldt's Voy., Relat. Hist., part i. p. 309.

† Macgregor's Travels in America.

sided, and the trees remained green for several months under water.*

Sicily, 1790.—On the 18th of March in the same year, at S. Maria di Niscemi, some miles from Terranuova, near the south coast of Sicily, the ground gradually sunk down for a circumference of three Italian miles, during seven shocks; and, in one place, to the depth of thirty feet. It continued to subside to the end of the month. Several fissures sent forth sulphur, petroleum, steam, and hot water; and a stream of mud, which flowed for two hours, and covered a space sixty feet long, and thirty broad. This happened far from both the ancient and modern volcanic district, in a group of strata consisting chiefly of blue clay.†

Java, 1786.—About the year 1786, an earthquake was felt at intervals, for the period of four months, in the neighbourhood of Batur, in Java, and an eruption followed. Various rents were formed, which emitted a sulphureous vapour; separate tracts sunk away, and were swallowed by the earth. Into one of these the rivulet Dotog entered, and afterwards continued to follow a subterraneous course. The village of Jampang was buried in the ground, with thirty-eight of its inhabitants, who had not time to escape. We are indebted to Dr. Horsfield for having verified the above-mentioned facts. ‡

Japan Isles, 1783.—In the province of Sinano, in the Isle of Nifon, the volcanic mountain of Asama-yama, situated north-east of the town of Komoro, was in violent eruption August 1. 1783. The eruption

* Humboldt's Voy., Relat. Hist., part ii. p. 632.

† Ferrara, Camp. fl., p. 51.

‡ Batav. Trans., vol. viii. p. 141.

was preceded by a frightful earthquake; gulphs are said to have opened every where, and many towns to have been swallowed up, while others were subsequently buried by lava.*

* Humboldt, Fragmens Asiatiques, &c., tom. i. p. 229.

CHAPTER XV.

EARTHQUAKE IN CALABRIA, 1783.

Earthquake in Calabria, February 5. 1783 — Shocks continued to the end of the year 1786 — Authorities — Area convulsed — Geological structure of the district — Difficulty of ascertaining changes of level (p. 261.) — Subsidence of the quay at Messina — Shift or fault in the Round Tower of Terranuova — Movement in the stones of two obelisks — Opening and closing of fissures — Large edifices engulphed — Dimensions of new caverns and fissures (p. 268.) — Gradual closing in of rents — Bounding of detached masses into the air — Landslips — Buildings transported entire to great distances (p. 275.) — New lakes — Currents of mud — Funnel-shaped hollows in alluvial plains — Fall of cliffs, and shore near Scilla inundated — State of Stromboli and Etna during the shocks — How earthquakes contribute to the formation of valleys (p. 281.) — Concluding remarks.

Duration of the shocks. — Of the numerous earthquakes which have occurred in different parts of the globe, during the last hundred years, that of Calabria, in 1783, is almost the only one of which the geologist can be said to have such a circumstantial account as to enable him fully to appreciate the changes which this cause is capable of producing in the lapse of ages. The shocks began in February, 1783, and lasted for nearly four years, to the end of 1786. Neither in duration, nor in violence, nor in the extent of territory moved, was this convulsion remarkable, when contrasted with many experienced in other countries,

both during the last and present century; nor were the alterations which it occasioned in the relative level of hill and valley, land and sea, so great as those effected by some subterranean movements in South America, in later times. The importance of the earthquake in question arises from the circumstance, that Calabria is the only spot hitherto visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information, to enable them to collect and describe with accuracy the physical facts which throw light on geological questions.

Authorities. — Among the numerous authorities, Vivenzio, physician to the King of Naples, transmitted to the court a regular statement of his observations during the continuance of the shocks; and his narrative is drawn up with care and clearness.* Francesco Antonio Grimaldi, then secretary of war, visited the different provinces at the king's command, and published a most detailed description of the permanent changes in the surface.† He measured the length, breadth, and depth of the different fissures and gulphs which opened, and ascertained their number in many provinces. His comments, moreover, on the reports of the inhabitants, and his explanations of their relations, are judicious and instructive. Pignataro, a physician residing at Monteleone, a town placed in the very centre of the convulsions, kept a register of the shocks, distinguishing them into four classes, according to their degree of violence. From his work, it appears that, in the year 1783, the number was 949,

* Istoria de' Tremuoti della Calabria del 1783.

† Descriz. de' Tremuoti Accad. nelle Calabria nel 1783. Napoli, 1784.

of which 501 were shocks of the first degree of force; and in the following year there were 151, of which 98 were of the first magnitude.

Count Ippolito, also, and many others, wrote descriptions of the earthquake; and the Royal Academy of Naples, not satisfied with these and other observations, sent a deputation from their own body into Calabria, before the shocks had ceased, who were accompanied by artists instructed to illustrate by drawings the physical changes of the district, and the state of ruined towns and edifices. Unfortunately these artists were not very successful in their representations of the condition of the country, particularly when they attempted to express, on a large scale, the extraordinary revolutions which many of the great and minor river-courses underwent. But many of the plates published by the Academy are valuable; and as they are little known, I shall frequently avail myself of them to illustrate the facts about to be described.*

In addition to these Neapolitan sources of information, our countryman, Sir William Hamilton, surveyed the district, not without some personal risk, before the shocks had ceased; and his sketch, published in the Philosophical Transactions, supplies many facts that would otherwise have been lost. He has explained in a rational manner many events which, as related in the language of some eye-witnesses, appeared marvellous and incredible. Dolomieu also examined Calabria during the catastrophe, and wrote an account of the earthquake, correcting a mistake

* Istoria de' Fenomeni del Tremoto, &c. nell' An. 1783, posta in luce dalla Real. Accad., &c. di Nap. Napoli, 1784. fol.

into which Hamilton had fallen, who supposed that a part of the tract shaken had consisted of volcanic tuff. It is, indeed, a circumstance which enhances the geological interest of the commotions which so often modify the surface of Calabria, that they are confined to a country where there are neither ancient nor modern rocks of volcanic or trappean origin; so that at some future time, when the era of disturbance shall have passed by, the cause of former revolutions will be as latent as in parts of Great Britain now occupied exclusively by ancient marine formations.

Extent of the area convulsed. — The convulsion of the earth, sea, and air extended over the whole of Calabria Ultra, the south-east part of Calabria Citra, and across the sea to Messina and its environs; a district lying between the 38th and 39th degrees of latitude. The concussion was perceptible over a great part of Sicily, and as far north as Naples; but the surface over which the shocks acted so forcibly as to excite intense alarm did not generally exceed five hundred square miles in area. The soil of that part of Calabria is composed chiefly, like the southern part of Sicily, of calcareo-argillaceous strata of great thickness, containing marine shells. This clay is sometimes associated with beds of sand and limestone. For the most part these formations resemble in appearance and consistency the Subapennine marls, with their accompanying sands and sandstones; and the whole group bears considerable resemblance, in the yielding nature of its materials, to most of our tertiary deposits in France and England. Chronologically considered, however, the Calabrian formations are comparatively of very modern date, and abound in fossil shells referrible to species now living in the Mediterranean.

We learn from Vivenzio that, on the 20th and 26th of March, 1783, earthquakes occurred in the islands of Zante, Cephalonia, and St. Maura; and in the last-mentioned island several public edifices and private houses were overthrown, and many people destroyed. It has been already shown that the Ionian Islands fall within the line of the same great volcanic region as Calabria; so that both earthquakes were probably derived from a common source, and it is not improbable that the bed of the whole intermediate sea was convulsed.

If the city of Oppido, in Calabria, be taken as a centre, and round that centre a circle be described, with a radius of twenty-two miles, this space will comprehend the surface of the country which suffered the greatest alteration, and where all the towns and villages were destroyed. The first shock, of February 5th, 1783, threw down, in two minutes, the greater part of the houses in all the cities, towns, and villages, from the western flanks of the Apennines in Calabria Ultra to Messina in Sicily, and convulsed the whole surface of the country. Another occurred on the 28th of March, with almost equal violence. The granitic chain which passes through Calabria from north to south, and attains the height of many thousand feet, was shaken but slightly by the first shock, but more rudely by some which followed.

Some writers have asserted that the wavelike movements which were propagated through the recent strata, from west to east, became very violent when they reached the point of junction with the granite, as if a reaction was produced where the undulatory movement of the soft strata was suddenly arrested by the more solid rocks. But the statement of Dolomieu

on this subject is most interesting, and, perhaps, in a geological point of view, the most important of all the observations which are recorded.*

The Apennines, he says, which consist in great part of hard and solid granite, with some micaceous and argillaceous schists, form bare mountains with steep sides, and exhibit marks of great degradation. At their base newer strata are seen of sand and clay, mingled with shells; a marine deposit containing such ingredients as would result from the decomposition of granite. The surface of this newer (*tertiary*) formation constitutes what is called the plain of Calabria — a platform which is flat and level, except where intersected by narrow valleys or ravines, which rivers and torrents have excavated sometimes to the depth of six hundred feet. The sides of these ravines are almost perpendicular; for the superior stratum, being bound together by the roots of trees, prevents the formation of a sloping bank. The usual effect of the earthquake, he continues, was to disconnect all those masses which either had not sufficient bases for their bulk, or which were supported only by lateral adherence. Hence it follows that throughout almost the whole length of the chain the soil which adhered to the granite at the base of the mountains Caulone, Esope, Sagra, and Aspramonte, slid over the solid and steeply inclined nucleus, and descended somewhat lower, leaving almost uninterruptedly from St. George to beyond St. Christina, a distance of from nine to ten miles, a chasm between the solid granitic nucleus and the sandy soil. Many lands slipping thus were carried to a considerable distance from their former position, so as entirely to cover

* Dissertation on the Calabrian Earthquake, &c., translated in Pinkerton's Voyages and Travels, vol. v.

others; and disputes arose as to whom the property which had thus shifted its place should belong.

From this account of Dolomieu we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact than at a greater distance from the mountains; phenomena very common in other parts of Italy at the junction of the Apennine and Subapennine formations.

The surface of the country often heaved, like the billows of a swelling sea, which produced a swimming in the head, like sea-sickness. It is particularly stated, in almost all the accounts, that just before each shock the clouds appeared motionless; and, although no explanation is offered of this phenomenon, it is obviously the same as that observed in a ship at sea when it pitches violently. The clouds seem arrested in their career as often as the vessel rises in a direction contrary to their course; so that the Calabrians must have experienced precisely the same motion on the land.

Trees, supported by their trunks, sometimes bent during the shocks to the earth, and touched it with their tops. This is mentioned as a well-known fact by Dolomieu; and he assures us that he was always on his guard against the spirit of exaggeration in which the vulgar are ever ready to indulge when relating these wonderful occurrences.

I shall now consider, in the first place, that class of physical changes produced by the earthquake which are connected with alterations in the relative level of the different parts of the land; and afterwards describe those which are more immediately connected with the derangement of the regular drainage of the

country, and where the force of running water co-operated with that of the earthquake.

Difficulty of ascertaining changes of level. — In regard to alterations of relative level, none of the accounts establish that they were on a considerable scale; but it must always be remembered that, in proportion to the area moved is the difficulty of proving that the general level has undergone any change, unless the sea-coast happens to have participated in the principal movement. Even then it is often impossible to determine whether an elevation or depression even of several feet has occurred, because there is nothing to attract notice in a band of shingle and sand of unequal breadth above the level of the sea running parallel to a coast; such bands generally marking the point reached by the waves during spring tides, or the most violent tempests. The scientific investigator has not sufficient topographical knowledge to discover whether the extent of beach has diminished or increased; and he who has the necessary local information scarcely ever feels any interest in ascertaining the amount of the rise or fall of the ground. Add to this the great difficulty of making correct observations, in consequence of the enormous waves which roll in upon a coast during an earthquake, and efface every landmark near the shore.

Subsidence of the Quay at Messina. — It is evidently in seaports alone that we can look for very accurate indications of slight changes of level; and when we find them, we may presume that they would not be rare at other points, if equal facilities of comparing relative altitudes were afforded. Grimaldi states (and his account is confirmed by Hamilton and others), that at Messina, in Sicily, the shore was rent; and the soil

along the port, which before the shock was perfectly level, was found afterwards to be inclined towards the sea, — the sea itself near the "Banchina" becoming deeper, and its bottom in several places disordered. The quay also sunk down about fourteen inches below the level of the sea, and the houses in its vicinity were much fissured. (*Phil. Trans.* 1783.)

Among various proofs of partial elevation and depression in the interior, the Academicians mention, in their Survey, that the ground was sometimes on the same level on both sides of new ravines and fissures, but sometimes there had been a considerable shifting, either by the upheaving of one side, or the subsidence of the other. Thus, on the sides of long rents in the territory of Soriano, the stratified masses had altered their relative position to the extent of from eight to fourteen palms (six to ten and a half feet).

Polistena.—Similar shifts in the strata are alluded

Fig. 31.

Deep fissure near Polistena, caused by the earthquake of 1783.

to in the territory of Polistena, where there appeared innumerable fissures in the earth. One of these was of great length and depth; and in parts the level of the corresponding sides was greatly changed. (See Fig. 31.)

Terranuova.—In the town of Terranuova some houses were seen uplifted above the common level, and others adjoining sunk down into the earth. In several streets the soil appeared thrust up, and abutted against the walls of houses; a large circular tower of solid masonry, part of which had withstood the general destruction, was divided by a vertical rent, and one side was upraised, and the foundations heaved out of the ground. It was compared by the Academicians to a great tooth half extracted from the alveolus, with the upper part of the fangs exposed. (See Fig. 32.)

Fig. 32.

Shift or "fault" in the round tower of Terranuova in Calabria, occasioned by the earthquake of 1783.

Along the line of this shift, or "fault," as it would be termed technically by miners, the walls were found to adhere firmly to each other, and to fit so well, that the only signs of their having been disunited was the want of correspondence in the courses of stone on either side of the rent.

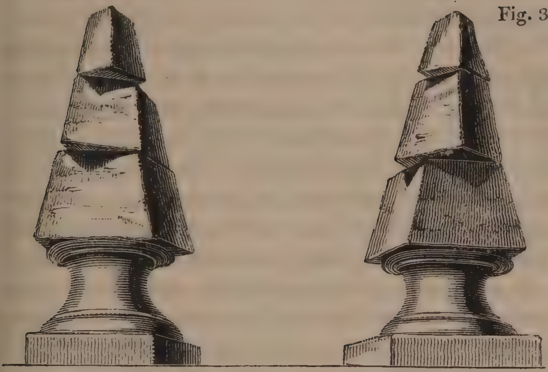
Dolomieu saw a stone well in the convent of the Augustins at Terranuova, which had the appearance of having been driven out of the earth. It resembled a small tower eight or nine feet in height, and a little inclined. This effect, he says, was produced by the consolidation and consequent sinking of the sandy soil in which the well was dug.

In some walls which had been thrown down, or violently shaken, in Monteleone, the separate stones were parted from the mortar, so as to leave an exact mould where they had rested; whereas in other cases the mortar was ground to dust between the stones.

It appears that the wave-like motions, and those which are called vorticose or whirling in a vortex, often produced effects of the most capricious kind. Thus, in some streets of Monteleone, every house was thrown down but one; in others, all but two; and the buildings which were spared were often scarcely in the least degree injured.

In many cities of Calabria, all the most solid buildings were thrown down, while those which were slightly built escaped; but at Rosarno, as also at Messina in Sicily, it was precisely the reverse, the massive edifices being the only ones that stood. Two obelisks (Fig. 33.) placed at the extremities of a magnificent façade in the convent of S. Bruno, in a small town called Stefano del Bosco, were observed to have undergone a movement of a singular kind. The shock

Fig. 33.



Shift in the stones of two obelisks in the Convent of S. Bruno.

which agitated the building is described as having been horizontal and vorticose. The pedestal of each obelisk remained in its original place; but the separate stones above were turned partially round, and removed sometimes nine inches from their position without falling.

Fissures.—It appears evident that a great part of the rending and fissuring of the ground was the effect of a violent motion from below upwards; and in a multitude of cases where the rents and chasms opened and closed alternately, we must suppose that the earth was by turns heaved up, and then let fall again. We may conceive the same effect to be produced on a small scale, if, by some mechanical force, a pavement composed of large flags of stone should be raised up, and then allowed to fall suddenly, so as to resume its original position. If any small pebbles happened to be lying on the line of contact of two flags, they would fall into the opening when the pavement rose, and be

swallowed up, so that no trace of them would appear after the subsidence of the stones. In the same manner, when the earth was upheaved, large houses, trees, cattle, and men were engulphed in an instant in chasms and fissures; and when the ground sank down again, the earth closed upon them, so that no vestige of them was discoverable on the surface. In many instances, individuals were swallowed up by one shock, and then thrown out again alive, together with large jets of water, by the shock which immediately succeeded.

At Jerocarne, a country which, according to the Academicians, was *lacerated* in a most extraordinary manner, the fissures ran in every direction "like cracks on a broken pane of glass" (see Fig. 34.); and, as a great portion of them remained open after the shocks, it is very possible that this country was permanently upraised. It was usual, as we learn from Dolo-

Fig. 34.

Fissures near Jerocarne, in Calabria, caused by the earthquake of 1783.

mieu, for the chasms and fissures throughout Calabria to run parallel to the course of some pre-existing gorges in their neighbourhood.

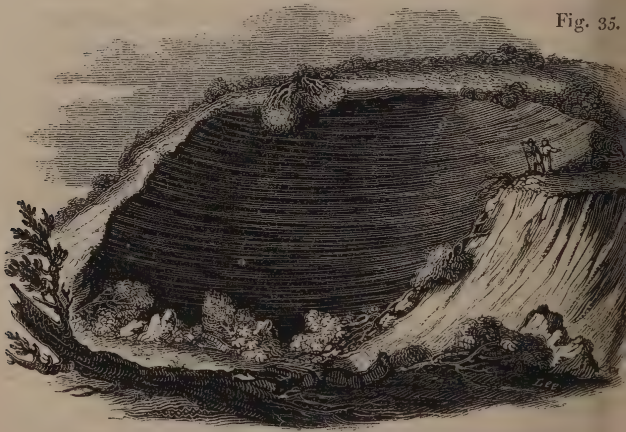
Houses engulphed. — In the vicinity of Oppido, the central point from which the earthquake diffused its violent movements, many houses were swallowed up by the yawning earth, which closed immediately over them. In the adjacent district, also, of Cannamaria four farm-houses, several oil-stores, and some spacious dwelling-houses were so completely engulphed in one chasm, that not a vestige of them was afterwards discernible. The same phenomenon occurred at Terranuova, S. Christina, and Sinopoli. The Academicians state particularly, that when deep abysses had opened in the argillaceous strata of Terranuova, and houses had sunk into them, the sides of the chasms closed with such violence, that, on excavating afterwards to recover articles of value, the workmen found the contents and detached parts of the buildings jammed together so as to become one compact mass. It is unnecessary to accumulate examples of similar occurrences; but so many are well authenticated during this earthquake in Calabria, that we may, without hesitation, yield assent to the accounts of catastrophes of the same kind repeated again and again in history, where whole towns are declared to have been engulphed, and nothing but a pool of water or tract of sand left in their place.

Chasm formed near Oppido. — On the sloping side of a hill near Oppido a great chasm opened; and, although a large quantity of soil was precipitated into the abyss, together with a considerable number of olive-trees and part of a vineyard, a great gulph remained after the shock, in the form of an amphi-

theatre, five hundred feet long and two hundred feet deep. (See Fig. 35.)

Dimensions of new fissures and chasms. — According to Grimaldi, many fissures and chasms, formed by the first shock of February 5th, were greatly widened lengthened, and deepened by the violent convulsions of March 28th. In the territory of San Fili this observer found a new ravine, half a mile in length, two feet and a half broad, and twenty-five feet deep; and another of similar dimensions in the territory of Rosarno. A ravine *nearly a mile long*, 105 feet broad, and thirty feet deep, opened in the district of Plaisano, where, also, two gulphs were caused — one in a place called Cerzulle, three quarters of a mile long, 150 feet broad, and above *one hundred feet deep;* and another at La Fortuna, nearly a quarter of a mile long, above thirty feet in breadth, and no less than 225 feet deep.

Fig. 35.



Chasm formed by the earthquake of 1783 near Oppido, in Calabria.

In the district of Fosolano three gulphs opened: one of these measured 300 feet square, and above thirty feet deep; another was nearly half a mile long, fifteen feet broad, and above thirty feet deep; the third was 750 feet square. Lastly, a calcareous mountain, called Zefirio, at the southern extremity of the Italian peninsula, was cleft in two for the length of nearly half a mile, and an irregular breadth of many feet. Some of these chasms were in the form of a crescent. The annexed cut (Fig. 36.) represents one by no means remarkable for its dimensions, which remained open by the side of a small pass over the hill of St. Angelo, near Soriano. The small river Mesima is seen in the foreground.

Formation of new lakes.—In the vicinity of Seminara, a lake was suddenly formed by the opening of a great chasm, from the bottom of which water issued. This lake was called Lago del Tolfilo. It extended

Fig. 36.

Chasm in the hill of St. Angelo, near Soriano, in Calabria, caused by the earthquake of 1783.

1785 feet in length, by 937 in breadth, and 52 in depth. The inhabitants, dreading the miasma of this stagnant pool, endeavoured, at great cost, to drain it by canals, but without success, as it was fed by springs issuing from the bottom of the deep chasm. A small circular subsidence occurred not far from Polistena, of which a representation is given in the annexed cut.

Fig. 37.

Circular pond near Polistena, in Calabria, caused by the earthquake in 1783.

Gradual closing in of fissures.—Sir W. Hamilton was shown several deep fissures in the vicinity of Mileto, which, although not one of them was above a foot in breadth, had opened so wide during the earthquake as to swallow up an ox and nearly one hundred goats. The Academicians also found, on their return through districts which they had passed at the commencement of their tour, that many rents had, in that short interval, gradually closed in, so that their width had diminished several feet, and the opposite walls had sometimes nearly met. It is natural that this should happen in argillaceous strata, while, in more solid

rocks, we may expect that fissures will remain open for ages. Should this be ascertained to be a general fact in countries convulsed by earthquakes, it may afford a satisfactory explanation of a common phenomenon in mineral veins. Such veins often retain their full size so long as the rocks consist of limestone, granite, or other indurated materials; but they contract their dimensions, become mere threads, or are even entirely cut off, where masses of an argillaceous nature are interposed. If we suppose the filling up of fissures with metallic and other ingredients to be a process requiring ages for its completion, it is obvious that the opposite walls of rents, where strata consist of yielding materials, must collapse or approach very near to each other before sufficient time is allowed for the accretion of a large quantity of veinstone.

Thermal waters augmented. — It is stated by Grimaldi, that the thermal waters of St. Euphemia, in Terra di Amato, which first burst out during the earthquake of 1638, acquired, in February, 1783, an augmentation both in quantity and degree of heat. This fact appears to indicate a connection between the heat of the interior and the fissures caused by the Calabrian earthquakes, notwithstanding the absence of volcanic rocks, either ancient or modern, in that district.

Bounding of detached masses into the air.—The violence of the movement of the ground upwards was singularly illustrated by what the Academicians call the "sbalzo," or bounding into the air, to the height of several yards, of masses slightly adhering to the surface. In some towns, a great part of the pavement stones were thrown up, and found lying with their lower sides uppermost. In these cases, we must suppose that they were propelled upwards by

the momentum which they had acquired; and that the adhesion of one end of the mass being greater than that of the other, a rotatory motion had been communicated to them. When the stone was projected to a sufficient height to perform somewhat more than a quarter of a revolution in the air, it pitched down on its edge, and fell with its lower side uppermost.

Effects of earthquakes on the excavation of valleys. — The next class of effects to be considered, are those more immediately connected with the formation of valleys, in which the action of water was often combined with that of the earthquake. The country agitated was composed, as before stated, chiefly of argillaceous strata, intersected by deep narrow valleys, sometimes from five to six hundred feet deep. As the boundary cliffs were in great part vertical, it will readily be conceived that, amidst the various movements of the earth, the precipices overhanging rivers, being without support on one side, were often thrown down. We find, indeed, that inundations produced by obstructions in river-courses are among the most disastrous consequences of great earthquakes in all parts of the world; for the alluvial plains in the bottoms of valleys are usually the most fertile and well-peopled parts of the whole country; and whether the site of a town is above or below a temporary barrier in the channel of a river, it is exposed to injury by the waters either of a lake or flood.

Landslips. — From each side of the deep valley or ravine of Terranuova, enormous masses of the adjoining flat country were detached, and cast down into the course of the river, so as to give rise to great lakes. Oaks, olive-trees, vineyards, and corn, were often seen growing at the bottom of the ravine, as little injured

as their former companions, which still continued to flourish in the plain above, at least five hundred feet higher, and at the distance of about three quarters of a mile. In one part of this ravine was an enormous mass, two hundred feet high, and about four hundred feet at its base, which had been detached by some former earthquake. It is well attested, that this mass travelled down the ravine nearly four miles, having been put in motion by the earthquake of the 5th of February. Hamilton, after examining the spot, declared that this phenomenon might be accounted for by the declivity of the valley, the great abundance of rain which fell, and the great weight of the alluvial matter which pressed behind it. Dolomieu also alludes to the fresh impulse derived from other masses falling, and pressing upon the rear of those first set in motion.

The first account sent to Naples of the two great slides or landslips above alluded to, which caused a great lake near Terranuova, was couched in these words: — "Two mountains on the opposite sides of a valley walked from their original position until they met in the middle of the plain, and there joining together, they intercepted the course of a river," &c. The expressions here used resemble singularly those applied to phenomena, probably very analogous, which are said to have occurred at Fez, during the great Lisbon earthquake, as also in Jamaica and Java at other periods.

Not far from Soriano, which was levelled to the ground by the great shock of February, a small valley, containing a beautiful olive-grove, called Fra Ramondo, underwent a most extraordinary revolution. Innumerable fissures first traversed the river-plain in all

directions, and absorbed the water until the argillaceous substratum became soaked, so that a great part of it was reduced to a state of fluid paste. Strange alterations in the outline of the ground were the consequence, as the soil to a great depth was easily moulded into any form. In addition to this change, the ruins of the neighbouring hills were precipitated into the hollow; and while many olives were uprooted, others remained growing on the fallen masses, and inclined at various angles (see Fig. 38.). The small river Caridi was entirely concealed for many days; and when at length it reappeared, it had shaped for itself an entirely new channel.

Fig. 38.

Changes of the surface at Fra Ramondo, near Soriano, in Calabria.

1. Portion of a hill covered with olives thrown down.
2. New bed of the river Caridi. 3. Town of Soriano.

Buildings transported entire to great distances.— Near Seminara, an extensive olive-ground and orchard

were hurled to a distance of two hundred feet, into a valley sixty feet in depth. At the same time a deep chasm was riven in another part of the high platform from which the orchard had been detached, and the river immediately entered the fissure, leaving its former bed completely dry. A small inhabited house, standing on the mass of earth carried down into the valley, went along with it entire, and without injury to the inhabitants. The olive-trees, also, continued to grow on the land which had slid into the valley, and bore the same year an abundant crop of fruit.

Two tracts of land on which a great part of the town of Polistena stood, consisting of some hundreds of houses, were detached into a contiguous ravine, and nearly across it, about half a mile from their original site; and what is most extraordinary, several of the inhabitants were dug out from the ruins alive and unhurt.

Two tenements, near Mileto, called the Macini and Vaticano, about a mile long, and half a mile broad, were carried for a mile down a valley. A thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance. According to Hamilton, the surface removed had been long undermined by rivulets, which were afterwards in full view on the bare spot deserted by the tenements. The earthquake seems to have opened a passage in the adjoining argillaceous hills, which admitted water charged with loose soil into the subterranean channels of the rivulets immediately under the tenements, so that the foundations of the ground set in motion by the earthquake were loosened. Another example of subsidence, where the edifices were not destroyed, is mentioned by Grimaldi,

as having taken place in the city of Catanzaro, the capital of the province of that name. The houses in the quarter called San Giuseppe subsided with the ground to various depths from two to four feet, but the buildings remained uninjured.

It would be tedious, and our space would not permit us, to follow the different authors through their local details of landslips produced in minor valleys; but they are highly interesting, as showing to how great an extent the power of rivers to widen valleys, and to carry away large portions of soil towards the sea, is increased where earthquakes are of periodical occurrence. Among other territories, that of Cinquefrondi was greatly convulsed, various portions of soil being raised or sunk, and innumerable fissures traversing the country in all directions (see Fig. 39.). Along the flanks of a small valley in this district there appears to have been an almost uninterrupted line of landslips.

Fig. 39.

Landslips near Cinquefrondi, caused by the earthquake of 1783.

Number of new-formed lakes. — Vivenzio states, that near Sitizzano a valley was nearly filled up to a level with the high grounds on each side, by the enormous masses detached from the boundary hills, and cast down into the course of two streams. By this barrier a lake was formed of great depth, about two miles long and a mile broad. The same author mentions that, upon the whole, there were fifty lakes occasioned during the convulsions; and he assigns localities to all of these. The government surveyors enumerated 215 lakes, but they included in this number many small ponds.

Currents of mud. — Near S. Lucido, among other places, the soil is described as having been "dissolved," so that large torrents of mud inundated all the low grounds, like lava. Just emerging from this mud, the tops only of trees and of the ruins of farm-houses were seen. Two miles from Laureana, the swampy soil in two ravines became filled with calcareous matter, which oozed out from the ground immediately before the first great shock. This mud, rapidly accumulating, began, ere long, to roll onward, like a flood of lava, into the valley, where the two streams uniting, moved forward with increased impetus from east to west. It now presented a breadth of 225 feet by fifteen in depth, and, before it ceased to move, covered a surface equal in length to an Italian mile. In its progress it overwhelmed a flock of thirty goats, and tore up by the roots many olive and mulberry-trees, which floated like ships upon its surface. When this calcareous lava had ceased to move, it gradually became dry and hard, during which process the mass was lowered seven feet and a half. It contained

fragments of earth of a ferruginous colour, and emitting a sulphureous smell.

Cones of sand thrown up.—Many of the appearances exhibited in the alluvial plains indicate clearly the alternate rising and sinking of the ground. The first effect of the more violent shocks was usually to dry up the rivers, but they immediately afterwards overflowed their banks. Along the alluvial plains, and in marshy places, an immense number of cones of sand were thrown up. These appearances Hamilton explains, by supposing that the first movement raised the fissured plain from below upwards, so that the rivers and stagnant waters in bogs sank down, or at least were not upraised with the soil. But when the ground returned with violence to its former position, the water was thrown up in jets through fissures.*

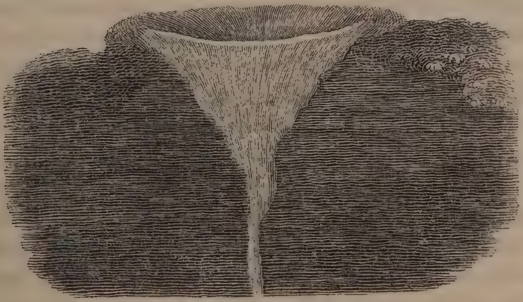
Fig. 40.

Circular hollows in the plain of Rosarno, formed by the earthquake of 1783.

* Phil. Trans., vol. lxxiii. p.180.

Formation of circular hollows.—In the report of the Academy, we find that some plains were covered with circular hollows, for the most part about the size of carriage-wheels, but often somewhat larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but, in general, they were filled with dry sand, sometimes with a concave surface, and at other times convex. (See fig. 40.). On digging down, they found them to be funnel-shaped, and the moist loose sand in the centre marked the tube up which the water spouted. The annexed cut represents a section of one of these inverted cones when the water had disappeared, and nothing but dry micaceous sand remained.

Fig. 41.



Section of one of the circular hollows formed in the plain of Rosarno.

Fall of the sea cliffs. — Along the sea-coast of the straits of Messina, near the celebrated rock of Scilla, the fall of huge masses detached from the bold and lofty cliffs overwhelmed many villas and gardens. At Gian Greco a continuous line of cliff, for a mile in length, was thrown down. Great agitation was frequently observed in the bed of the sea during the

shocks, and, on those parts of the coast where the movement was most violent all kinds of fish were taken in abundance, and with unusual facility. Some rare species, as that called Cicirelli, which usually lie buried in the sand, were taken on the surface of the waters in great quantity. The sea is said to have boiled up near Messina, and to have been agitated as if by a copious discharge of vapours from its bottom.

Shore near Scilla inundated. — The Prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of the 5th of February, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and suddenly a great mass was torn from the contiguous Mount Jaci, and thrown down with a dreadful crash upon the plain. Immediately afterwards, the sea, rising more than twenty feet above the level of this low tract, rolled foaming over it, and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing with it some of the people and animals it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged Prince, with 1430 of his people, was destroyed.

State of Stromboli and Etna during the shocks. — The inhabitants of Pizzo remarked that, on the 5th of February, 1783, when the first great shock afflicted Calabria, the volcano of Stromboli, which is in full view of that town, and at the distance of about fifty miles, smoked less, and threw up a less quantity of inflamed matter, than it had done for some years previously. On the other hand, the great crater of Etna

is said to have given out a considerable quantity of vapour towards the beginning, and Stromboli towards the close, of the commotions. But as no eruption happened from either of these great vents during the whole earthquake, the sources of the Calabrian convulsions, and of the volcanic fires of Etna and Stromboli, appear to be very independent of each other; unless, indeed, they have the same mutual relation as Vesuvius and the volcanos of the Phlegræan Fields and Ischia, a violent disturbance in one district serving as a safety-valve to the other, and both never being in full activity at once.

Excavation of valleys.—It is impossible for the geologist to consider attentively the effect of this single earthquake of 1783, and to look forward to the alterations in the physical condition of the country to which a continued series of such movements will hereafter give rise, without perceiving that the formation of valleys by running water can never be understood, if we consider the question independently of the agency of earthquakes. Rivers do not begin to act, as some seem to imagine, when a country is already elevated far above the level of the sea, but while it is *rising* or *sinking* by successive movements. Whether Calabria is now undergoing any considerable change of relative level, in regard to the sea, or is, upon the whole, nearly stationary, is a question which our observations, confined almost entirely to the last half century, cannot possibly enable us to determine. But we know that strata, containing species of shells identical with those now living in the contiguous parts of the Mediterranean, have been raised in that country, as they have in Sicily, to the height of several thousand feet.

Now, those geologists who grant that the present course of Nature in the inanimate world has been unchanged since the existing species of animals were in being, will not feel surprise that the Calabrian streams and rivers have cut out of such comparatively modern strata a great system of valleys, varying in depth from fifty to six hundred feet, and often several miles wide, if they consider how numerous must have been the earthquakes which lifted those recent marine strata to so prodigious a height. Some speculators, indeed, who disregard the analogy of existing Nature, and who are always ready to assume that her forces were more energetic in by-gone ages, may dispense with a long series of movements, and suppose that Calabria "rose like an exhalation" from the deep, after the manner of Milton's Pandemonium. But such an hypothesis would deprive them of that peculiar removing force required to form a regular system of deep and wide valleys; for *time*, which they are so unwilling to assume, is essential to the operation. Time must be allowed in the intervals between distinct convulsions, for running water to clear away the ruins caused by landslips, otherwise the fallen masses will serve as buttresses, and prevent the succeeding earthquake from exerting its full power. The sides of the valley must be again cut away by the stream, and made to form precipices and overhanging cliffs, before the next shock can take effect in the same manner.

If a single violent convulsion agitate at once an entire hydrographical basin, or if the shocks follow each other too rapidly, the previously existing valleys will be annihilated, instead of being modified and enlarged. Every stream will in that case be compelled to begin its operations anew, and to open for itself a

passage through strata before undisturbed, instead of continuing to deepen and widen channels already in great part excavated. On the other hand, if, consistently with all that is known from observation of the laws which regulate subterranean movements, we consider their action to have been intermittent; if sufficient periods have always intervened between the severer shocks to allow the drainage of the country to be nearly restored to its original state, then both the kind and degree of force are supplied which may enable running water to hollow out a valley of any depth and size consistent with the degree of elevation above the sea which the district in question may happen at any time to have attained during a succession of physical revolutions.

Notwithstanding the great derangement caused by violent earthquakes, there is an evident tendency in running water to remain constant to the same connected series of valleys. The softening of the soaked soil is invariably greatest in the channels of rivers and in alluvial plains. The water is absorbed in an infinite number of rents; and when the ground is swelled with water, it is reduced almost to a state of mud by the vehement agitation of the ground in every direction, and often for several years consecutively. The erosive and transporting action of running water is, therefore, facilitated in the tracts already excavated.

When we read of the drying up and desertion of the channels of rivers, the accounts most frequently refer to their deflection into some other part of the same alluvial plain, perhaps several miles distant. Under certain circumstances, a change of level may undoubtedly force the water to flow over into some

distinct hydrographical basin; but even then it will fall immediately into valleys already formed. Provided, therefore, we suppose the elevation and subsidence of mountain-chains to be a gradual process, there is no difficulty in explaining how the rivers draining large continents have converted ravines into valleys, and enlarged and deepened valleys to an enormous extent. On the contrary, the signs of slow and gradual action so manifest in the sinuosities and other characters of valleys, are admirably reconcileable with the great width and depth of the excavations, if we are content not only to suppose a great succession of ordinary earthquakes, but also the usual intervals of time between the shocks.

It may be observed, that earthquakes alone could never give rise to a regular system of valleys ramifying from a main trunk, like the small vessels from the great arteries of the human body. On the contrary, they would in the course of time destroy every system of valleys on the globe, were it not for the agency of aqueous causes. We learn from history that, ever since the first Greek colonists settled in Calabria, that region has been subject to devastation by earthquakes; and, for the last century and a half, ten years have seldom elapsed without a shock: but the severer convulsions have not only been separated by intervals of twenty, fifty, or one hundred years; but have not affected precisely the same points when they recurred. Thus the earthquake of 1783, although confined within the same geographical limits as that of 1638, and not very inferior in violence, visited, according to Grimaldi, very different districts. The points where the local intensity of the force is developed being thus

perpetually varied, more time is allowed for the removal of separate mountain masses thrown into river channels by each shock.

When chasms and deep hollows open at the bottom of valleys, they must often be filled with those "mud lavas" before described; and these must be extremely analogous to the enormous ancient deposits of mud which are seen in many countries, as in the basin of the Tay, Isla, and North Esk rivers, for example, in Scotland — alluvions hundreds of feet thick, which are neither stratified nor laminated like the ordinary sediment which subsides from water. Whenever a landslip blocks up a river, these currents of mud will be arrested, and accumulate to an enormous depth.

The portion of the Calabrian valleys formed within the last three thousand years may be inconsiderable in amount, compared to that previously formed, just as the lavas which have flowed from Etna since the historical era constitute but a small proportion of the whole cone. But as a continued series of such eruptions as man has witnessed would reproduce another cone like Etna, so a sufficient number of earthquakes like that of 1783 would enable torrents and rivers to re-excavate all the Calabrian valleys, if they were now to be entirely obliterated. It must be evident that more change is effected in two centuries in the width and depth of the valleys of that region, than in many thousand years in a country as undisturbed by earthquakes as Great Britain. For the same reason, therefore, that he who desires to comprehend the volcanic phenomena of Central France will repair to Vesuvius, Etna, or Hecla, so they who aspire to explain the mode in which valleys are formed, must

visit countries where earthquakes are of frequent occurrence. For we may be assured, that the power which uplifted our more ancient tertiary strata of marine origin to more than a thousand feet above the level of the sea, co-operated at some former epoch with the force of rivers in the removal of large portions of rock and soil, just as the elevatory power which has upraised new strata to the height of several thousand feet in the south of Italy has caused those formations to be already intersected by deep valleys and ravines.

Number of persons who perished during the earthquake.—The number of persons who perished during the earthquake in the two Calabrias and Sicily is estimated by Hamilton at about forty thousand, and about twenty thousand more died by epidemics, which were caused by insufficient nourishment, exposure to the atmosphere, and malaria, arising from the new stagnant lakes and pools.

By far the greater number were buried under the ruins of their houses; but many were burnt to death in the conflagrations which almost invariably followed the shocks. These fires raged the more violently in some cities, such as Oppido, from the immense magazines of oil which were consumed.

Many persons were engulphed in deep fissures, especially the peasants, when flying across the open country, and their skeletons may perhaps be buried in the earth to this day, at the depth of several hundred feet.

When Dolomieu visited Messina after the shock of Feb. 5th, he describes the city as still presenting, at least at a distance, an imperfect image of its ancient splendour. Every house was injured, but the walls were standing: the whole population had taken refuge

in wooden huts in the neighbourhood, and all was solitude and silence in the streets: it seemed as if the city had been desolated by the plague, and the impression made upon his feelings was that of melancholy and sadness. " But when I passed over to Calabria, and first beheld Polistena, the scene of horror almost deprived me of my faculties; my mind was filled with mingled compassion and terror: nothing had escaped; all was levelled with the dust; not a single house or piece of wall remained; on all sides were heaps of stone so destitute of form, that they gave no conception of there ever having been a town on the spot. The stench of the dead bodies still rose from the ruins. I conversed with many persons who had been buried for three, four, and even for five days; I questioned them respecting their sensations in so dreadful a situation, and they agreed that, of all the physical evils they endured, thirst was the most intolerable; and that their mental agony was increased by the idea that they were abandoned by their friends, who might have rendered them assistance." *

It is supposed that about a fourth part of the inhabitants of Polistena, and of some other towns, were buried alive, and might have been saved had there been no want of hands; but in so general a calamity, where each was occupied with his own misfortunes, or those of his family, aid could rarely be obtained. Neither tears, nor supplications, nor promises of high rewards, were listened to. Many acts of self-devotion, prompted by parental and con-

* Dissertation on the Calabrian Earthquake, &c. translated in Pinkerton's Voyages and Travels, vol. v.

jugal tenderness, or by friendship, or the gratitude of faithful servants, are recorded; but individual exertions were, for the most part, ineffectual. It frequently happened, that persons in search of those most dear to them could hear their moans,—could recognize their voices,—were certain of the exact spot where they lay buried beneath their feet, yet could afford them no succour. The piled mass resisted all their strength, and rendered their efforts of no avail.

At Terranuova, four Augustin monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support an immense pile of ruins, made their cries heard for the space of four days. One only of the brethren of the whole convent was saved, and "of what avail was his strength to remove the enormous weight of rubbish which had overwhelmed his companions?" He heard their voices die away gradually; and when afterwards their four corpses were disinterred, they were found clasped in each other's arms. Affecting narratives are preserved of mothers saved after the fifth, sixth, and even seventh day of their interment, when their infants or children had perished with hunger.

It might have been imagined that the sight of sufferings such as these would have been sufficient to awaken sentiments of humanity and pity in the most savage breasts, but nothing could exceed the atrocity of conduct and moral depravity displayed by the Calabrian peasants: they abandoned the farms, and flocked in great numbers into the towns—not to rescue their countrymen from a lingering death, but to plunder. They dashed through the streets, fearless of danger, amid tottering walls and clouds of dust, trampling

beneath their feet the bodies of the wounded and half buried, and often stripping them, while yet living, of their clothes.*

Concluding remarks. — But to enter more fully into these details would be foreign to the purpose of the present work, and several volumes would be required to give the reader a just idea of the sufferings which the inhabitants of many populous districts have undergone during the earthquakes of the last 140 years. A bare mention of the loss of life — as that fifty or a hundred thousand souls perished in one catastrophe — conveys to the reader no idea of the extent of misery inflicted: we must learn, from the narratives of eye-witnesses, the various forms in which death was encountered, the numbers who escaped with loss of limbs or serious bodily injuries, and the multitude who were suddenly reduced to penury and want. It has been often remarked, that the dread of earthquakes is strongest in the minds of those who have experienced them most frequently; whereas, in the case of almost every other danger, familiarity with peril renders men intrepid. The reason is obvious — scarcely any part of the mischief apprehended in this instance is imaginary; the first shock is often the most destructive; and, as it may occur in the dead of the night, or if by day, without giving the least warning of its approach, no forethought can guard against it; and when the convulsion has begun, no skill, or courage, or presence of mind, can point out the path of safety. During the intervals, of uncertain duration, between the more fatal shocks, slight tremors of the soil are not unfrequent; and as these sometimes precede more

* Dolomieu, ibid.

violent convulsions, they become a source of anxiety and alarm. The terror arising from this cause alone is of itself no inconsiderable evil.

Although sentiments of pure religion are frequently awakened by these awful visitations, yet we more commonly find that an habitual state of fear, a sense of helplessness, and a belief in the futility of all human exertions, prepare the minds of the vulgar for the influence of a demoralizing superstition.

Where earthquakes are frequent, there can never be perfect security of property under the best government; for industry cannot be assured of reaping the fruits of its labour; and the most daring acts of outrage may occasionally be perpetrated with impunity, when the arm of the law is paralysed by the general consternation. It is hardly necessary to add, that the progress of civilization and national wealth must be retarded by convulsions which level cities to the ground, destroy harbours, render roads impassable, and cause the most cultivated valley-plains to be covered with lakes, or the ruins of adjoining hills.

Those geologists who imagine that, at remote periods ere man became a sojourner on earth, the volcanic agency was more energetic than now, should be careful to found their opinion on strict geological evidence, and not permit themselves to be biassed, as they have often been, by a notion, that the disturbing force would probably be mitigated for the sake of man.

I shall endeavour to point out in the sequel, that the general tendency of subterranean movements, when their effects are considered for a sufficient lapse of ages, is eminently beneficial, and that they constitute an essential part of that mechanism by which the integrity of the habitable surface is preserved, and the

very existence and perpetuation of dry land secured. Why the working of this same machinery should be attended with so much evil, is a mystery far beyond the reach of our philosophy, and must probably remain so until we are permitted to investigate, not our planet alone and its inhabitants, but other parts of the moral and material universe with which they may be connected. Could our survey embrace other worlds, and the events, not of a few centuries only, but of periods as indefinite as those with which geology renders us familiar, some apparent contradictions might be reconciled, and some difficulties would doubtless be cleared up. But even then, as our capacities are finite, while the scheme of the universe may be infinite, both in time and space, it is presumptuous to suppose that all sources of doubt and perplexity would ever be removed. On the contrary, they might, perhaps, go on augmenting in number; for it has been justly said, that the greater the circle of light, the greater the boundary of darkness by which it is surrounded.*

* Sir H. Davy, Consolations in Travel, p. 246.

CHAPTER XVI.

EARTHQUAKES OF THE EIGHTEENTH CENTURY—*continued.*

Earthquake of Guatimala, 1773 — Java, 1772 — Truncation of a lofty cone — St. Domingo, 1770 — Colombia, 1766 — Lisbon 1755 — Shocks felt throughout Europe, Northern Africa, and the West Indies — Great wave (p. 298.) — Conception Bay, 1750 — Permanent elevation — Peru, 1746 — Kamtschatka, 1737 — Java, 1699 (p. 304.) — Rivers obstructed by landslips — Subsidence in Sicily, 1693 — Moluccas, 1693 — Jamaica, 1692 — Large tracts engulphed — Portion of Port Royal sunk — Amount of change in the last 140 years — Elevation and subsidence of land in Bay of Baiæ (p. 312.) — Evidence of the same afforded by the Temple of Serapis.

In the preceding chapters we have considered a small part of those earthquakes only which have occurred during the last fifty years, of which accurate and authentic descriptions happen to have been recorded. We may next proceed to examine some of earlier date, respecting which information of geological interest has been obtained.

Mexico, June, 1773. — The town of Guatimala was founded, in 1742, on the side of a volcano, in a valley about three miles wide, opening to the South Sea; nine years afterwards it was destroyed by an earthquake, and again, in 1773, during an eruption of the volcano. The ground on which the town stood gaped open in deep fissures, until at length, after five days, an abyss opened, and the city, with all its riches, and

eight thousand families, was swallowed up. Every vestige of its former existence was entirely obliterated, and the spot is now indicated by a frightful desert, four leagues distant from the present town.*

Java, 1772 — *Truncation of a lofty cone.* — In the year 1772, Papandayang, formerly one of the loftiest volcanos in the island of Java, was in eruption. Before all the inhabitants on the declivities of the mountain could save themselves by flight, the ground began to give way, and a great part of the volcano fell in and disappeared. It is estimated that an extent of ground of the mountain itself and its immediate environs, fifteen miles long and full six broad, was by this commotion swallowed up in the bowels of the earth. Forty villages were destroyed, some being engulphed and some covered by the substances thrown out on this occasion, and 2957 of the inhabitants perished. A proportionate number of cattle were also killed, and most of the plantations of cotton, indigo, and coffee in the adjacent districts were buried under the volcanic matter. This catastrophe appears to have resembled, although on a grander scale, that of the ancient Vesuvius in the year 79. The cone was reduced in height from nine thousand to about five thousand feet; and, as vapours still escape from the crater on its summit, a new cone may one day rise out of the ruins of the ancient mountain, as the modern Vesuvius has risen from the remains of Somma.†

* Von Hoff — Dodsley's Ann. Regist., vol. xvi. p. 149.

† Dr. Horsfield, Batav. Trans., vol. viii. p. 26. Dr. H. informs me that he has seen this truncated mountain; and, though he did not ascend it, he has conversed with those who have examined it. Raffles's account (History of Java, vol. i.) is derived from Horsfield.

Caucasus, 1772.—About the year 1772, an earthquake convulsed the ground in the province at Beshtau, in the Caucasus, so that part of the hill Metshuka sunk into an abyss.*

St. Domingo, 1770.—During a tremendous earthquake which destroyed a great part of St. Domingo, innumerable fissures were caused throughout the island, from which mephitic vapours emanated and produced an epidemic. *Hot springs* burst forth in many places where there had been no water before; but after a time they ceased to flow.†

Colombia, 1766.—On the 21st of October, 1766, the ground was agitated at once at Cumana, at Caraccas, at Maracaybo, and on the banks of the rivers Casanare, the Meta, the Orinoco, and the Ventuario. These districts were much fissured, and great fallings in of the earth took place in the mountain Paurari: Trinidad was violently shaken. A small island in the Orinoco, near the rock Aravacoto, sunk down and disappeared.‡ At the same time the ground was raised in the sea near Cariaco, where the Point Del Gardo was enlarged. A rock also rose up in the river Guarapica, near the village of Maturin.§ The shocks continued in Colombia hourly for fourteen months.

Hindostan, 1762.—The town of Chittagong, in Bengal, was violently shaken by an earthquake, on the 2d of April 1762, the earth opening in many places, and throwing up water and mud of a sulphu-

* Pallas's Travels in Southern Russia.

† Essai sur l'Hist. Nat. de l'Isle de St. Domingue, Paris, 1776.

‡ Humboldt's Personal Narrative, vol. iv. p. 45.; and Saggio di Storia Americana, vol. ii. p. 6.

§ Humboldt, Voy. Relat. Hist., part i. p. 307.; and part ii. p. 23.

reous smell. At a place called Bardavan a large river was dried up; and at Bakar Churak, near the sea, a tract of ground sunk down, and 200 people with all their cattle were lost. Unfathomable chasms are described as remaining open in many places after the shocks, and towns which subsided several cubits were overflowed with water; among others, Deep Gong, which was submerged to the depth of seven cubits. Two volcanos are said to have opened in the Secta Cunda hills. The shock was also felt at Calcutta.*

Lisbon, 1755.—In no part of the volcanic region of southern Europe has so tremendous an earthquake occurred in modern times as that which began on the 1st of November, 1755, at Lisbon. A sound of thunder was heard underground, and immediately afterwards a violent shock threw down the greater part of that city. In the course of about six minutes, sixty thousand persons perished. The sea first retired and laid the bar dry; it then rolled in, rising fifty feet or more above its ordinary level. The mountains of Arrabida, Estrella, Julio, Marvan, and Cintra, being some of the largest in Portugal, were impetuously shaken, as it were, from their very foundations; and some of them opened at their summits, which were split and rent in a wonderful manner, huge masses of them being thrown down into the subjacent valleys.† Flames are related to have issued from these mountains, which are supposed to have been electric; they are also said to have smoked; but vast clouds of dust may have given rise to this appearance.

* Dodsley's Ann. Regist., 1763. For other particulars, see Phil. Trans., vol. liii.

† Hist. and Philos. of Earthquakes, p. 317.

Subsidence of the Quay. — The most extraordinary circumstance which occurred at Lisbon during the catastrophe was the subsidence of a new quay, built entirely of marble at an immense expense. A great concourse of people had collected there for safety, as a spot where they might be beyond the reach of falling ruins; but, suddenly, the quay sank down with all the people on it, and not one of the dead bodies ever floated to the surface. A great number of boats and small vessels anchored near it, all full of people, were swallowed up, as in a whirlpool.* No fragments of these wrecks ever rose again to the surface, and the water in the place where the quay had stood is stated, in many accounts, to be unfathomable; but Whitehurst says, he ascertained it to be one hundred fathoms.†

In this case, we must either suppose that a certain tract sank down into a subterranean hollow, which would cause a "fault" in the strata to the depth of six hundred feet, or we may infer, as some have done, from the entire disappearance of the substances engulphed, that a chasm opened and closed again. Yet, in adopting this latter hypothesis, we must suppose that the upper part of the chasm, to the depth of one hundred fathoms, remained open.

Area over which the earthquake extended. — The great area over which this Lisbon earthquake extended is very remarkable. The movement was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even the West Indies,

* Rev. C. Davy's Letters, vol. ii. Letter ii. p. 12., who was at Lisbon at the time, and ascertained that the boats and vessels said to have been swallowed were missing.

† On the Formation of the Earth, p. 55.

felt the shock on the same day. A seaport, called St. Ubes, about twenty miles south of Lisbon, was engulphed. At Algiers and Fez, in Africa, the agitation of the earth was equally violent; and at the distance of eight leagues from Morocco, a village with the inhabitants to the number of about eight or ten thousand persons, together with all their cattle, were swallowed up. Soon after the earth closed again over them.

Shocks felt at sea. — The shock was felt at sea, on the deck of a ship to the west of Lisbon, and produced very much the same sensation as on dry land. Off St. Lucar, the captain of the ship Nancy felt his vessel so violently shaken, that he thought she had struck the ground; but, on heaving the lead, found a great depth of water. Captain Clark, from Denia, in latitude 36° 24′ N., between nine and ten in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. Another ship, forty leagues west of St. Vincent, experienced so violent a concussion, that the men were thrown a foot and a half perpendicularly up from the deck. In Antigua and Barbadoes, as also in Norway, Sweden, Germany, Holland, Corsica, Switzerland, and Italy, tremors and slight oscillations of the ground were felt.

Rate at which the movement travelled. — The agitation of lakes, rivers, and springs, in Great Britain, was remarkable. At Loch Lomond, in Scotland, for example, the water, without the least apparent cause, rose against its banks, and then subsided below its usual level. The greatest perpendicular height of this swell was two feet four inches. It is said that the movement of this earthquake was undulatory, and that it travelled at the rate of twenty miles a minute, its

velocity being calculated by the intervals between the time when the first shock was felt at Lisbon, and its time of occurrence at other distant places.*

Great wave and retreat of the sea. — A great wave swept over the coast of Spain, and is said to have been sixty feet high at Cadiz. At Tangier, in Africa, it rose and fell eighteen times on the coast. At Funchal, in Madeira, it rose full fifteen feet perpendicular above high-water mark, although the tide, which ebbs and flows there seven feet, was then at half ebb. Besides entering the city, and committing great havoc, it overflowed other seaports in the island. At Kinsale, in Ireland, a body of water rushed into the harbour, whirled round several vessels, and poured into the market-place.

It was before stated that the sea first retired at Lisbon; and this retreat of the ocean from the shore, at the commencement of an earthquake and its subsequent return in a violent wave, is a common occurrence. In order to account for the phenomenon, Michell imagined a subsidence at the bottom of the sea, from the giving way of the roof of some cavity in consequence of a vacuum produced by the condensation of steam. Such condensation, he observes, might be the first effect of the introduction of a large body of water into fissures and cavities already filled with steam, before there has been sufficient time for the heat of the incandescent lava to turn so large a supply of water into steam, which being soon accomplished causes a greater explosion.

Another proposed explanation is, the sudden rise of

* Michell on the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. p. 566. 1760.

the land which would cause the sea to abandon immediately the ancient line of coast; and if the shore, after being thus heaved up, should fall again to its original level, the ocean would return. This theory, however, will not account for the facts observed during the Lisbon earthquake; for the retreat preceded the wave, not only on the coast of Portugal, but also at the island of Madeira, and several other places. If the upheaving of the coast of Portugal had caused the retreat, the motion of the waters, when propagated to Madeira, would have produced a wave previous to the retreat. Nor could the motion of the waters at Madeira have been caused by a different local earthquake; for the shock travelled from Lisbon to Madeira in two hours, which agrees with the time which it required to reach other places equally distant.*

The following is, perhaps, the most probable solution of the problem which has yet been offered:—Suppose a portion of the bed of the sea to be suddenly upheaved, the first effect will be to raise over the elevated part a body of water, the momentum of which will carry it much above the level it will afterwards assume, causing a draught or receding of the water from the neighbouring coasts, followed immediately by the return of the displaced water, which will also be impelled by its momentum, much farther and higher on the coast than its former level.†

St. Domingo, 1751.—On the 15th of September, 1751, an earthquake began in several of the West India Islands; and on the 21st of November, a violent shock destroyed the capital of St. Domingo, Port au

* Michell, Phil. Trans., vol. li. p.614.

† Quarterly Review, No. 86. p.459.

Prince. Part of the coast, twenty leagues in length, sank down, and has ever since formed a bay of the sea.*

Chili, 1750. — On the 24th of May, 1750, the ancient town of Conception, otherwise called Penco, was totally destroyed by an earthquake, and the sea rolled over it. The ancient port was rendered entirely useless, and the inhabitants built another town ten miles from the sea-coast, in order to be beyond the reach of similar inundations.

Proofs of elevation of twenty-four feet.—During a late survey of Conception Bay, Captains Beechey and Belcher discovered that the ancient harbour, which formerly admitted all large merchant vessels which went round the Cape, is now occupied by a reef of sandstone, certain points of which project above the sea at low water, the greater part being very shallow. A tract of a mile and a half in length, where, according to the report of the inhabitants, the water was formerly four or five fathoms deep, is now a shoal; consisting, as our hydrographers found, of hard sandstone, so that it cannot be supposed to have been formed by recent deposits of the river Biobio, an arm of which carries down loose micaceous sand into the same side of the bay. Besides, it is a well-known fact that ever since the shock of 1750, no vessels have been able to approach within a mile and a half of the ancient port of Penco. That shock, therefore, uplifted the bed of the sea to the height of twenty-four feet at the least, and, most probably, the adjoining coast shared in the elevation: for an enormous bed of shells of the same species as those now living in the

* Hist. de l'Acad. des Sciences. 1752. Paris.

bay, are seen raised above high-water mark along the beach, filled with micaceous sand like that which the Biobio now conveys to the bay. These shells, as well as others, which cover the adjoining hills of mica-schist to the height of from 1000 to 1500 feet, have lately been examined by experienced conchologists in London, and identified with those taken at the same time in a living state from the bay and its neighbourhood.*

Ulloa, therefore, was perfectly correct in his statement that, at various heights above the sea between Talcaguana and Conception, "mines were found of various sorts of shells used for lime of the very same kinds as those found in the adjoining sea." Among them he mentions the great mussel called Choros, and two others, which he describes. Some of these, he says, are entire, and others broken; they occur at the bottom of the sea, in four, six, ten, or twelve fathom water, where they adhere to a sea-plant called Cochayuyo. They are taken in dredges, and have no resemblance to those found on the shore or in shallow water; yet beds of them occur at various heights on the hills. "I was the more pleased with the sight," he adds, "as it appeared to me a convincing proof of the universality of the deluge, although I am not ignorant that some have attributed their position to other causes; but an unanswerable confutation of their subterfuge is, that the various sorts of shells which compose these strata, both in the plains and mountains, are the very same with those found in the bay."† Perhaps the diluvian theory of this distinguished navigator, the

* Captain Belcher has shown me these shells, and the collection has been examined by Mr. Broderip.

† Ulloa's Voyage to South America, vol. ii. book viii. ch. vi.

companion of Condamine, may account for his never having recorded even reports of changes in the relative level of land and sea on the shores of South America. He could not, however, have given us a relation of the rise of the reef above alluded to; for the destruction of Penco happened a few years after the publication of his Voyages.

If we duly consider these facts, so recently brought to light, as well as the elevation before mentioned of the coast at Valparaiso in 1822, we shall be less sceptical than Raspe, in regard to an event for which Hooke had cited Purchas's Travels. In that passage it was stated, that "a certain sea-coast in a province of South America, called Chili, was, during a violent earthquake, propelled upwards with such force and velocity, that some ships on the sea were grounded in it, and the sea receded to a distance." Raspe, being himself of opinion that all the continents had been upraised gradually by earthquakes from the sea, admitted that the circumstance was not impossible; but he complains that Purchas had interpolated the account of the earthquake (which happened, probably, at the close of the seventeenth century) into Da Costa's History of the West Indies.*

Peru, 1746.—Peru was visited, on the 28th of October, 1746, by an earthquake, which is declared to have been more tremendous and extensive than even that of Lisbon in 1755. In the first twenty-four hours, two hundred shocks were experienced. The ocean twice retired and returned impetuously upon the land: Lima was destroyed, and part of the coast near Callao was converted into a bay; four other harbours, among

* De Novis Insulis, p. 120. 1753.

which were Cavalla and Guanape, shared the same fate. There were twenty-three ships and vessels, great and small, in the harbour of Callao, of which nineteen were sunk; and the other four, among which was a frigate called St. Fermin, were carried by the force of the waves to a great distance up the country. The number of the inhabitants in this city amounted to four thousand. Two hundred only escaped, twenty-two of whom were saved on a small fragment of the fort of Vera Cruz, which remained as the only memorial of the site of the town after this dreadful inundation.

A volcano in Lucanas burst forth the same night, and such quantities of water descended from the cone that the whole country was overflowed; and in the mountain near Patao, called Conversiones de Caxamarquilla, three other volcanos burst out, and frightful torrents of water swept down their sides.*

In regard to changes of level, I have heard that the submerged arches of a church, and the position of several buildings, indicate a subsidence on the ancient site of Callao; but this report requires confirmation. Mr. Fryer states that the isle of San Lorenzo in the bay of Callao appears to have been raised up by volcanic action, and partially so at a comparatively recent period; for he found at considerable heights above the sea the shells of *Concholepas*, *Pecten purpureus*, *Sigaretus concavus*, and others, in great abundance, and retaining their colours almost as fresh as those now living in the Pacific.†

Kamtschatka, 1737.—The eastern side of the Peninsula of Kamtschatka, at Awatchka Bay, was shaken by

* Ulloa's Voyage, vol. ii. book vii. chap. vii.

† Letter read to Geol. Soc., March, 1835.

an earthquake on October the 6th, 1737. The sea was violently agitated, and overflowed the land to an immense height, and then withdrew so far as to lay bare its bottom between the first and second of the Kurile Isles. The shape of the ground was greatly changed. Several plains were uplifted and formed hills; and, on the other hand, many subsidences occasioned inland lakes and new bays on the coast.*

Martinique, 1727.—In the year 1727, a hill is said to have sunk down in Martinique during an earthquake.†

Iceland, 1725.—In Iceland during the eruption of the volcano Leirhnukur, in 1725-6, a tract of high land sank down, and formed a lake; and, half a mile from the same place, a hill rose and converted a lake into dry land.‡

Teneriffe, 1706.—May 5th, 1706, a lateral eruption of Teneriffe took place south of the harbour of Garachico, which was overwhelmed with lava. Many springs disappeared, and there were such changes of level as to alter the whole face of the country, hills having risen up where there were plains before.§

Java, 1699.—On the 5th of January, 1699, a terrible earthquake visited Java, and no less than 208 considerable shocks were reckoned. Many houses in Batavia were overturned, and the flame and noise of a volcanic eruption were seen and heard in that city, which were afterwards found to proceed from Mount Salak ||, a volcano six days' journey distant. Next morning the Batavian river, which has its rise from

* Kracheninikon by Chappe d'Auteroche, p. 337.

† Geog. of America, Schlözer, part ii. p. 554.

‡ Dureau de la Malle, Géog. de la Mer Noire, p. 203.

§ Humboldt and Bonpland, Voy. Relat. Hist., part i. p. 177.

|| Misspelt Sales in Hooke's Account.

that mountain, became very high and muddy, and brought down abundance of bushes and trees, half burnt. The channel of the river being stopped up, the water overflowed the country round the gardens about the town, and some of the streets, so that fishes lay dead in them. All the fish in the river, except the carps, were killed by the mud and turbid water. A great number of drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down by the current; and, "notwithstanding," observes one of the writers, "that a crododile is amphibious, several of them were found dead among the rest." *

It is stated, that seven hills bounding the river sank down, by which is merely meant, as by similar expressions in the description of the Calabrian earthquakes, seven great landslips. These hills, descending some from one side of the valley and some from the other, filled the channel, and the waters then finding their way under the mass, flowed out thick and muddy. The Tangaran river was also dammed up by nine hills, and in its channel were large quantities of drift trees. Seven of its tributaries also are said to have been "covered up with earth." A high tract of forest land, between the two great rivers before mentioned, is described as having been changed into an open country, destitute of trees, the surface being spread over with a fine red clay. This part of the account may, perhaps, merely refer to the sliding down of woody tracts into the valleys, as happened to so many extensive vineyards and olive grounds in Calabria, in 1783. The close packing of large trees in the Batavian river is represented as very remarkable, and it attests in a striking

* Hooke's Posthumous Works, p. 437. 1705.

manner the destruction of soil bordering the valleys which had been caused by floods and landslips.*

Quito, 1698.—In Quito, on the 19th of July, 1698, during an earthquake, a great part of the crater and summit of the volcano Carguairazo fell in, and a stream of water and mud issued from the broken sides of the hill.†

Sicily, 1693.—Shocks of earthquakes spread over all Sicily in 1693, and on the 11th of January the city of Catania and forty-nine other places were levelled to the ground, and about one hundred thousand people killed. The bottom of the sea, says Vicentino Bonajutus, sank down considerably, both in ports, inclosed bays, and open parts of the coast, and water bubbled up along the shores. Numerous long fissures of various breadths were caused, which threw out sulphureous water; and one of them, in the plain of Catania (the delta of the Simeto), at the distance of four miles from the sea, sent forth water as salt as the sea. The stone buildings of a street in the city of Noto, for the length of half a mile, sank into the ground, and remained hanging on one side. In another street, an opening large enough to swallow a man and horse appeared.‡

Moluccas, 1693.—The small isle of Sorea, which consists of one great volcano, was in eruption in the year 1693. Different parts of the cone fell, one after the other, into a deep crater, until almost half the space of the island was converted into a fiery lake. Most of the inhabitants fled to Banda; but great pieces of the mountain continued to fall down, so that the lake of lava became wider; and finally the whole popu-

* Phil. Trans. 1700. † Humboldt, Atl. Pit., p. 106.

‡ Phil. Trans. 1693-4.

lation was compelled to emigrate. It is stated that, in proportion as the burning lake increased in size, the earthquakes were less vehement.*

Jamaica, 1692. — In the year 1692, the island of Jamaica was visited by a violent earthquake; the ground swelled and heaved like a rolling sea, and was traversed by numerous cracks, two or three hundred of which were often seen at a time opening and then closing rapidly again. Many people were swallowed up in these rents; some the earth caught by the middle, and squeezed to death; the heads of others only appeared above ground; and some were first engulphed, and then cast up again with great quantities of water. Such was the devastation, that even at Port Royal, then the capital, where more houses are said to have been left standing than in the whole island beside, three quarters of the buildings, together with the ground they stood on, sank down with their inhabitants entirely under water.

Subsidence in the harbour. — The large store-houses on the harbour side subsided, so as to be twenty-four, thirty-six, and forty-eight feet under water; yet many of them appear to have remained standing, for it is stated that, after the earthquake, the mast-heads of several ships wrecked in the harbour, together with the chimney-tops of houses, were just seen projecting above the waves. A tract of land round the town, about a thousand acres in extent, sank down in less than one minute, during the first shock, and the sea immediately rolled in. The Swan frigate, which was repairing in the wharf, was driven over the tops of many buildings, and then thrown upon one of the roofs,

* Phil. Trans. 1693.

through which it broke. The breadth of one of the streets is said to have been doubled by the earthquake.

According to Mr. De la Beche, the part of Port Royal described as having sunk was built upon newly formed land, consisting of sand in which piles had been driven; and the *settlement* of this loose sand, charged with the weight of heavy houses, may have given rise to the subsidences alluded to.* There can be no doubt that a waving motion of the earth, accompanied by an inroad of the sea, might affect loose sand, while solid rock might remain unmoved; but, after attentively considering the original documents, and conversing with persons who, ninety years after, saw some of the submerged houses, I am inclined to believe that there were various and unequal subsidences of the land at Port Royal, independently of any sliding and undermining of the sands.

At several thousand places in Jamaica, the earth is related to have opened. On the north of the island, several plantations, with their inhabitants, were swallowed up, and a lake appeared in their place, covering above a thousand acres, which afterwards dried up, leaving nothing but sand and gravel, without the least sign that there had ever been a house or a tree there. Several tenements at Yallowes were buried under landslips; and one plantation was removed half a mile from its place, the crops continuing to grow upon it uninjured. Between Spanish Town and Sixteen-mile Walk, the high and perpendicular cliffs bounding the river fell in, stopped the passage of the river, and flooded the latter place for nine days, so that the

* Manual of Geol., p. 133, second edition.

people "concluded it had been sunk as Port Royal was." But the flood at length subsided, for the river had found some new passage at a great distance.

Mountains shattered. — The Blue and other of the highest mountains are declared to have been strangely torn and rent. They appeared shattered, and half-naked, no longer affording a fine green prospect, as before, but stripped of their woods and natural verdure. The rivers on these mountains first ceased to flow for about twenty-four hours, and then brought down into the sea, at Port Royal and other places, several hundred thousand tons of timber, which looked like floating islands on the ocean. The trees were in general barked, most of their branches having been torn off in the descent. It is particularly remarked in this, as in the narratives of so many earthquakes, that fish were taken in great numbers on the coast during the shocks. The correspondents of Sir Hans Sloane, who collected with care the accounts of eye-witnesses of the catastrophe, refer constantly to *subsidences*, and some supposed the whole of Jamaica to have sunk down.*

Reflections on the amount of change in the last one hundred and forty years. — I have now only enumerated the earthquakes of the last 140 years, respecting which facts illustrative of geological inquiries are on record. Even if my limits permitted, it would be a tedious and unprofitable task to examine all the obscure and ambiguous narratives of similar events of earlier epochs; although, if the places were now examined by geologists well practised in the art of interpreting the monuments of physical changes, many events which have happened within the historical era might

* Phil. Trans. 1694.

still be determined with precision. It must not be imagined that, in the above sketch of the occurrences of a short period, I have given an account of all, or even the greater part, of the mutations which the earth has undergone by the agency of subterranean movements. Thus, for example, the earthquake of Aleppo, in the present century, and of Syria, in the middle of the eighteenth, would doubtless have afforded numerous phenomena, of great geological importance, had those catastrophes been described by scientific observers. The shocks in Syria, in 1759, were protracted for three months, throughout a space of ten thousand square leagues; an area compared to which that of the Calabrian earthquake of 1783 was insignificant. Accon, Saphat, Balbeck, Damascus, Sidon, Tripoli, and many other places, were almost entirely levelled to the ground. Many thousands of the inhabitants perished in each; and, in the valley of Balbeck alone, twenty thousand men are said to have been victims to the convulsion. In the absence of scientific accounts, it would be as irrelevant to our present purpose to enter into a detailed account of such calamities, as to follow the track of an invading army, to enumerate the cities burnt or rased to the ground, and reckon the number of individuals who perished by famine or the sword.

Deficiency of historical records.—If such, then, be the amount of ascertained changes in the last 140 years, notwithstanding the extreme deficiency of our records during that brief period, how important must we presume the physical revolutions to have been in the course of thirty or forty centuries, during which some countries habitually convulsed by earthquakes have been peopled by civilized nations! Towns en-

gulphed during one earthquake may, by repeated shocks, have sunk to enormous depths beneath the surface, while the ruins remain as imperishable as the hardest rocks in which they are enclosed. Buildings and cities, submerged, for a time, beneath seas or lakes, and covered with sedimentary deposits, must, in some places, have been re-elevated to considerable heights above the level of the ocean. The signs of these events have, probably, been rendered visible by subsequent mutations, as by the encroachments of the sea upon the coast, by deep excavations made by torrents and rivers, by the opening of new ravines, and chasms, and other effects of natural agents, so active in districts agitated by subterranean movements.

If it be asked why, if such wonderful monuments exist, so few have hitherto been brought to light, we reply — because they have not been searched for. In order to rescue from oblivion the memorials of former occurrences, the inquirer must know what he may reasonably expect to discover; and under what peculiar local circumstances. He must be acquainted with the action and effect of physical causes, in order to recognize, explain, and describe correctly the phenomena when they present themselves.

The best known of the great volcanic regions, of which the boundaries were sketched in the ninth chapter, is that which includes Southern Europe, Northern Africa, and Central Asia; yet nearly the whole, even of this region, must be laid down in a geological map, as "Terra Incognita." Even Calabria may be regarded as unexplored, as also Spain, Portugal, the Barbary States, the Ionian Isles, the Morea, Asia Minor, Cyprus, Syria, and the countries between the Caspian and Black Seas. We are, in truth, beginning to ob-

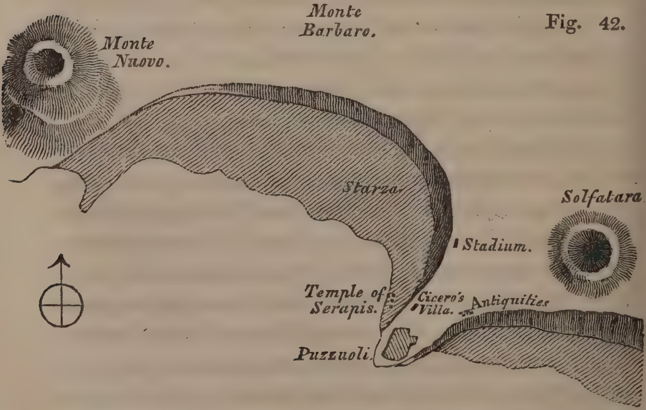
tain some insight into one small spot of that great zone of volcanic disturbance, the district around Naples; a tract by no means remarkable for the violence of the earthquakes which have convulsed it.

If, in this part of Campania, we are enabled to establish, that considerable changes in the relative level of land and sea have taken place since the Christian era, it is all that we could have expected; and it is to recent antiquarian and geological research, not to history, that we are principally indebted for the information. I shall now proceed to lay before the reader some of the results of modern investigations in the Bay of Baiæ and the adjoining coast.

PROOFS OF ELEVATION AND SUBSIDENCE IN THE BAY OF BAIÆ.

Temple of Jupiter Serapis. — This celebrated monument of antiquity affords, in itself alone, unequivocal

Fig. 42.



Ground plan of the coast of the Bay of Baiæ, in the environs of Puzzuoli.

evidence that the relative level of land and sea has changed twice at Puzzuoli since the Christian era; and each movement, both of elevation and subsidence, has exceeded twenty feet. Before examining these proofs, I may observe, that a geological examination of the coast of the Bay of Baiæ, both on the north and south of Puzzuoli, establishes, in the most satisfactory manner, an elevation, at no remote period, of more than twenty feet, and, at one point, of more than thirty feet; and the evidence of this change would have been complete, even if the temple had, to this day, remained undiscovered.

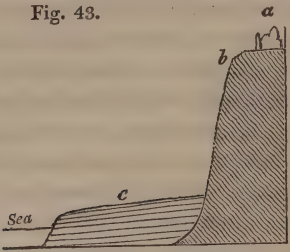
Coast south of Puzzuoli. — If we coast along the shore from Naples to Puzzuoli, we find, on approaching the latter place, that the lofty and precipitous cliffs of indurated tuff, resembling that of which Naples is built, retire slightly from the sea; and that a low level tract of fertile land, of a very different aspect, intervenes between the present sea-beach, and what was evidently the ancient line of coast.

The inland cliff may be seen opposite the small island of Nisida, about two miles and a half south-east of Puzzuoli,* where, at the height of thirty-two feet above the level of the sea, Mr. Babbage observed an ancient mark, such as might have been worn by the waves; and, upon further examination, discovered that, along that line, the face of the perpendicular rock, consisting of very hard tuff, was covered with barnacles (*Balanus sulcatus*, Lamk.), and drilled by boring testacea. Some of the hollows of the Lithodomi contained the shells; while others were filled with

* See Map, Pl. IV. Fig. 2.

the valves of a species of Arca.* Nearer to Puzzuoli, the inland cliff is eighty feet high, and as perpendicular as if it was still undermined by the waves. At its

Fig. 43.



a. Antiquities on hill S.E. of Puzzuoli.
b. Ancient cliff now inland.
c. Terrace composed of recent submarine deposit.

base, a new deposit, constituting the fertile tract above alluded to, attains a height of about twenty feet above the sea; and, since it is composed of regular sedimentary deposits, containing marine shells, its position proves that, subsequently to its formation, there has been a change of more than twenty feet in the relative level of land and sea.

The sea encroaches on these new incoherent strata; and as the soil is valuable, a wall has been built for its protection: but when I visited the spot in 1828, the waves had swept away part of this rampart, and exposed to view a regular series of strata of tuff, more or less argillaceous, alternating with beds of pumice and lapilli, and containing great abundance of marine shells, of species now common on this coast, and amongst

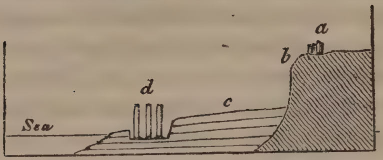
* Mr. Babbage examined this spot in company with Mr. Head, in June, 1828, and has shown me numerous specimens of the shells collected here, and in the Temple of Serapis.

them Cardium rusticum, Ostrea edulis, Donax trunculus (Lamk.), and others. The strata vary from about a foot to a foot and a half in thickness, and one of them contains abundantly remains of works of art, tiles, squares of mosaic pavement of different colours, and small sculptured ornaments, perfectly uninjured. Intermixed with these I collected some teeth of the pig and ox. These fragments of building occur below as well as above strata containing marine shells. Puzzuoli itself stands chiefly on a promontory of the older tufaceous formation, which cuts off the new deposit, although I detected a small patch of the latter in a garden under the town.

From the town the ruins of a mole, called Caligula's Bridge, run out into the sea. This mole consists of a number of piers and arches; and Mr. Babbage found, on the sixth pier, perforations of lithodomi four feet above the level of the sea; and near the termination of the mole, on the last pier but one, marks of the same ten feet above the level of the sea, together with great numbers of balani and flustra.

Coast north of Puzzuoli. — If we then pass to the north of Puzzuoli, and examine the coast between that town and Monte Nuovo, we find a repetition of analogous phenomena. The sloping sides of Monte Barbaro slant down within a short distance of the coast, and terminate in an inland cliff of moderate elevation, to which the geologist perceives at once that the sea must, at some former period, have extended. Between this cliff and the sea is a low plain or terrace, called La Starza, corresponding to that before described on the south-east of the town; and, as the sea encroaches rapidly, fresh sections of the strata may readily be obtained, of which the annexed is an example.

Fig. 44.



a. Remains of Cicero's villa, N. side of Puzzuoli.*
b. Ancient cliff now inland.
c. Terrace composed of recent submarine deposits.
d. Temple of Serapis.

Section on the shore north of the town of Puzzuoli:—

	Ft.	In.
1. Vegetable soil	1	0
2. Horizontal beds of pumice and scoriæ, with broken fragments of unrolled bricks, bones of animals, and marine shells . . .	1	6
3. Beds of lapilli, containing abundance of marine shells, principally Cardium rusticum, Donax trunculus, Lam., Ostrea edulis, Triton cutaceum, Lam., and Buccinum serratum, Brocchi, the beds varying in thickness from one to eighteen inches. . .	10	0
4. Argillaceous tuff, containing bricks and fragments of buildings not rounded by attrition.	1	6

The thickness of many of these beds varies greatly as we trace them along the shore, and sometimes the whole group rises to a greater height than at the point above described. The surface of the tract which they

* The spot here indicated on the summit of the cliff, is that from which Hamilton's view, plate 26, Campi Phlegræi, is taken, and on which, he observes, Cicero's villa, called the Academia, anciently stood.

compose appears to slope gently upwards towards the base of the old cliffs.

Now, if these appearances presented themselves on the eastern or southern coast of England, a geologist would naturally endeavour to seek an explanation in some local depression of high-water mark, in consequence of a change in the set of the tides and currents: for towns have been built, like ancient Brighton, on sandy tracts intervening between the old cliff and the sea, and, in some cases, they have been finally swept away by the return of the ocean. On the other hand, the inland cliff at Lowestoffe, in Suffolk, remains, as was before stated, at some distance from the shore, and the low green tract called the Ness may be compared to the low flat called La Starza, near Puzzuoli.* But there are scarce any tides in the Mediterranean; and, to suppose that sea to have sunk generally from twenty to twenty-five feet since the shores of Campania were covered with sumptuous buildings, is an hypothesis obviously untenable. The observations, indeed, made during modern surveys on the moles and cothons (docks) constructed by the ancients in various ports of the Mediterranean, have proved that there has been no sensible variation of level in that sea during the last two thousand years.†

Thus we arrive, without the aid of the celebrated temple, at the conclusion, that the recent marine deposit at Puzzuoli was upraised in modern times above the level of the sea, and that not only this change of position, but the accumulation of the modern strata, was posterior to the destruction of many edifices, of

* See p. 30.

† On the authority of Captain W. H. Smyth, R.N.

which they contain the imbedded remains. If we now examine the evidence afforded by the temple itself, it appears, from the most authentic accounts, that the three pillars now standing erect continued, down to the middle of the last century, half buried in the new marine strata before described. The upper part of the columns, being concealed by bushes, had not attracted, until the year 1749, the notice of antiquaries; but, when the soil was removed in 1750, they were seen to form part of the remains of a splendid edifice, the pavement of which was still preserved, and upon it lay a number of columns of African breccia and of granite. The original plan of the building could be traced distinctly; it was of a quadrangular form, seventy feet in diameter, and the roof had been supported by forty-six noble columns, twenty-four of granite, and the rest of marble. The large court was surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still used for medicinal purposes, issues now just behind the building, and the water, it is said, of this spring was conveyed by marble ducts into the chambers.

Many antiquaries have entered into elaborate discussions as to the deity to which this edifice was consecrated; but Signor Carelli, who has written the last able treatise on the subject *, endeavours to show that all the religious edifices of Greece were of a form essentially different; that the building, therefore, could never have been a temple; that it corresponded to the public bathing-rooms at many of our watering-places; and, lastly, that if it had been a temple, it could not have been dedicated to Serapis, the worship of the

* Dissertazione esergetica sulla Sagra Architettura degli Antichi.

Egyptian god being strictly prohibited, at the time when this edifice was in use, by the senate of Rome.

Perforation of the columns by Lithodomous shells.— It is not for the geologist to offer an opinion on these topics; and I shall, therefore, designate this valuable relic of antiquity by its generally received name, and proceed to consider the memorials of physical changes inscribed on the three standing columns in most legible characters by the hand of nature. (See Plate of Temple.*) These pillars, which have been carved each out of a single block of marble, are forty-two feet in height. An horizontal fissure nearly intersects one of the columns; the other two are entire. They are all slightly out of the perpendicular, inclining somewhat to the south-west, that is, towards the sea.† Their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone, about nine feet in height, where the marble has been pierced by a species of marine perforating bivalve — *Lithodomus*, Cuv.‡ The holes of these animals are pear-shaped, the external opening being minute, and gradually increasing downwards. At the bottom of the cavities, many shells are still found, notwithstanding the great numbers that

* The representation of the present state of the temple in this Plate has been carefully reduced from that given by the Canonico Andrea de Jorio, Ricerche sul Tempio di Serapide, in Puzzuoli. Napoli, 1820.

† This appears from the measurement of Captain Basil Hall, R.N., Proceedings of Geol. Soc., No. 38. p. 114. The fact of the three standing columns having been each formed out of a single stone, was first pointed out to me by Mr. James Hall, and is important, as helping to explain why they were not shaken down.

‡ Modiola lithophaga, Lam. Mytilus lithophagus, Linn.

have been taken out by visitors; in many the valves of a species of arca, an animal which conceals itself in small hollows, occur. The perforations are so considerable in depth and size, that they manifest a long-continued abode of the lithodomi in the columns; for, as the inhabitant grows older and increases in size, it bores a larger cavity, to correspond with the increasing magnitude of its shell. We must, consequently, infer a long-continued immersion of the pillars in sea-water, at a time when the lower part was covered up and protected by strata of tuff and the rubbish of buildings; the highest part, at the same time, projecting above the waters, and being consequently weathered, but not materially injured.

On the pavement of the temple lie some columns of marble, which are perforated in the same manner in certain parts; one, for example, to the length of eight feet, while, for the length of four feet, it is uninjured. Several of these broken columns are eaten into, not only on the exterior, but on the cross fracture, and, on some of them, other marine animals have fixed themselves.* All the granite pillars are untouched by lithodomi. The platform of the temple, which is not perfectly even, is at present about one foot below high-water mark (for there are small tides in the Bay of Naples); and the sea, which is only one hundred feet distant, soaks through the intervening soil. The upper part of the perforations, then, are at least twenty-three feet above high-water mark; and it is clear, that the columns must have continued for a long time in an

* Serpula contortuplicata, Linn., and Vermilia triquetra, Lam. These species, as well as the Lithodomus, are now inhabitants of the neighbouring sea.

erect position, immersed in salt water. After remaining for many years submerged, they must have been upraised to the height of about twenty-three feet above the level of the sea.

Temples and Roman roads under water. — So far the information derived from the temple corroborates that before obtained from the new strata in the plain of La Starza, and proves nothing more. But, as the temple could not have been built originally at the bottom of the sea, it must have first sunk down below the waves, and afterwards have been elevated. Of such subsidences there are numerous independent proofs in the Bay of Baiæ. Not far from the shore, to the north-west of the Temple of Serapis, are the ruins of a Temple of Neptune, and a Temple of the Nymphs, now under water. The columns of the former edifice stand erect in five feet water, their upper portions just rising to the surface of the sea. The pedestals are doubtless buried in the mud; so that if this part of the bottom of the bay should hereafter be elevated, the exhumation of this temple might take place after the manner of that of Serapis. Both these buildings probably participated in the movement which raised the Starza; but, either they were deeper under water than the Temple of Serapis, or they were not raised up again to so great a height. There are also two Roman roads under water in the bay, one reaching from Puzzuoli towards the Lucrine Lake, which may still be seen, and the other near the Castle of Baiæ. The ancient mole, too, of Puzzuoli, before alluded to, has the water up to a considerable height of the arches; whereas Brieslak justly observes, it is next to certain that the piers must formerly have reached the surface

before the springing of the arches*; so that, although the phenomena before described prove that this mole has been uplifted ten feet above the level at which it once stood, it is still evident that it has not yet been restored to its original position.

A modern writer also reminds us, that these effects are not so local as some would have us believe; for on the opposite side of the Bay of Naples, on the Sorrentine coast, which, as well as Puzzuoli, is subject to earthquakes, a road, with some fragments of Roman buildings, is covered to some depth by the sea. In the island of Capri, also, which is situated some way at sea, in the opening of the Bay of Naples, one of the palaces of Tiberius is now covered with water.† They who have attentively considered the effects of earthquakes, before enumerated, as having occurred during the last 140 years, will not feel astonished at these signs of alternate elevation and depression of the bed of the sea and the adjoining coast during the course of eighteen centuries; but, on the contrary, they will be very much astonished if future researches fail to bring to light similar indications of change in almost all regions of volcanic disturbances.

That buildings should have been submerged, and afterwards upheaved, without being entirely reduced to a heap of ruins, will appear no anomaly, when we recollect that, in the year 1819, when the delta of the

* Voy. dans la Campanie, tome ii. p. 162.

† Mr. Forbes, Physical Notices of the Bay of Naples. Ed. Journ. of Sci., No. II., new series, p. 280. October 1829. When I visited Puzzuoli, and arrived at the above conclusions, I knew nothing of Mr. Forbes's observations, which I first saw on my return to England the year following.

Indus sank down, the houses within the fort of Sindree subsided beneath the waves, without being overthrown. In like manner, in the year 1692, the buildings around the harbour of Port Royal, in Jamaica, descended suddenly to the depth of between thirty and fifty feet under the sea, without falling. Even on small portions of land transported to a distance of a mile, down a declivity, tenements, like those near Mileto, in Calabria, were carried entire. At Valparaiso buildings were left standing, when their foundations, together with a long tract of the Chilian coast, were permanently upraised to the height of several feet in 1822. It is true that, in the year 1750, when the bottom of the sea in the harbour of Penco was suddenly uplifted to the extraordinary elevation of twenty-four feet above its former level, the buildings of that town were thrown down; but we might still suppose that a great portion of them would have escaped, had the walls been supported on the exterior and interior with a deposit, like that which surrounded and filled to the height of ten or twelve feet the Temple of Serapis at Puzzuoli.

Periods when the Temple of Serapis sank and rose.— The next subject of inquiry is the era when these remarkable changes took place in the Bay of Baiæ. It appears that, in the Atrium of the Temple of Serapis, inscriptions were found in which Septimius Severus and Marcus Aurelius record their labours in adorning it with precious marbles.* We may, therefore, conclude, that it existed at least down to the third century of our era in its original position; and it may have been built at the close of the second cen-

* Brieslak, Voy. dans la Campanie, tom. ii., p. 167.

tury. On the other hand, we have evidence that the marine deposit forming the flat land, called La Starza, was still covered by the sea in the year 1530, or just eight years anterior to the tremendous explosion of Monte Nuovo. Mr. Forbes, has lately pointed out the distinct testimony of an old Italian writer, Loffredo, in confirmation of this important point.* Writing in 1580, Loffredo declares that, fifty years previously the sea washed the base of the hills which rise from the flat land before alluded to; and at that time he expressly tells us, that a person *might have fished* from the site of those ruins which are now called the Stadium. (See Fig. 42.) Hence it follows, that the subsidence of the ground happened at some period between the third century, when the temple was still standing, and the beginning of the sixteenth century, when its site was still submerged.

Now, in this interval the only two events which are recorded in the imperfect annals of the dark ages are, the eruption of the Solfatara in 1198, and an earthquake in 1488, by which Puzzuoli was ruined. It is at least highly probable, that earthquakes, which preceded the eruption of the Solfatara, which is very near the temple (see Fig. 42.), caused a subsidence, and the pumice and other matters ejected from that volcano might have fallen in heavy showers into the sea, and would thus immediately have covered up the lower part of the columns, and preserved them from the action of the sea and from lithodomous perforations. The waves might afterwards have thrown down many pillars, and formed strata of broken fragments of buildings, intermixed with volcanic ejections,

* Ed. Journ. of Science, new series, No. II. p. 281.

and thus have caused those strata, containing works of art and shells, which extend for several miles along the coast. Mr. Babbage, after carefully examining several incrustations of carbonate of lime, such as the waters of the hot spring might have deposited, adhering to the walls and columns of the temple at different heights, as also the distinct marks of ancient lines of water level, visible below the zone of lithophagous perforations, has come to the conclusion, and, I think, proved, that the subsidence of the building was not sudden, or at one period only, but gradual, and by successive movements.*

As to the re-elevation of the depressed tract, that may also have occurred at different periods, since earthquakes are not unfrequent in this country. Jorio cites two authentic documents in illustration of this point. The first, dated Oct. 1503, is a deed, written in Italian, by which Ferdinand and Isabella grant to the University of Puzzuoli a portion of land, "where the sea is drying up" (Che va seccando el mare); the second, a document in Latin, dated May 23, 1511, or nearly eight years after, by which Ferdinand grants to the city a certain territory around Puzzuoli, where the ground *is dried up* from the sea (desiccatum).†

It is perfectly evident, however, from Loffredo's statement, that the principal elevation of the low tract called La Starza took place after the year 1530, and some time before the year 1580; and from this alone we might have suspected that the change happened in the year 1538, when Monte Nuovo was formed. But, fortunately, we are not left in the slightest doubt that such was the date of this re-

* Proceedings of Geol. Soc., No. 36. March 1834.

† Sul Tempio di Serap. chap. viii.

markable event. Sir William Hamilton has given us two original letters describing the eruption of 1538, the first of which, by Falconi, dated 1538, contains the following passages.* "It is now two years since there have been frequent earthquakes at Puzzuoli, Naples, and the neighbouring parts. On the day and in the night before the eruption (of Monte Nuovo), above twenty shocks, great and small, were felt. The eruption began on the 29th of September, 1538. It was on a Sunday, about one o'clock in the night, when flames of fire were seen between the hot baths and Tripergola. In a short time the fire increased to such a degree, that it burst open the earth in this place, and threw up so great a quantity of ashes and pumice stones, mixed with water, as covered the whole country. The next morning (after the formation of Monte Nuovo) the poor inhabitants of Puzzuoli quitted their habitations in terror, covered with the muddy and black shower which continued the whole day in that country—flying from death, but with death painted in their countenances. Some with their children in their arms, some with sacks full of their goods; others leading an ass, loaded with their frighttened family, towards Naples; others carrying quantities of birds of various sorts, that had fallen dead at the beginning of the eruption; others, again, with fish which they had found, and which were to be met with in plenty on the shore, the sea having *left them dry for a considerable time.* I accompanied Signor Moramaldo to behold the wonderful effects of the eruption. The sea had retired on the side of Baiæ, *abandoning a considerable tract,* and the shore appeared almost entirely dry, from the quantity of ashes and broken

* Campi Phlegræi, p. 70.

pumice-stones thrown up by the eruption. I saw two springs *in the newly discovered ruins:* one before the house that was the queen's, of hot and salt water," &c.

So far Falconi; the other account is by Pietro Giacomo di Toledo, which begins thus:—"It is now two years since this province of Campagna has been afflicted with earthquakes, the country about Puzzuoli much more so than any other parts: but the 27th and the 28th of the month of September last, the earthquakes did not cease day or night in the town of Puzzuoli: that plain which lies between Lake Avernus, the Monte Barbaro, and the sea, was *raised a little*, and many cracks were made in it, from some of which issued water; at the same time the sea immediately adjoining the plain *dried up about two hundred paces*, so that the fish were left on the sand a prey to the inhabitants of Puzzuoli. At last, on the 29th of the same month, about two o'clock in the night, the earth opened," &c. Now, both these accounts, written immediately after the birth of Monte Nuovo, agree in expressly stating that the sea retired, and one mentions that its bottom was upraised. To this elevation we have already seen that Hooke, writing at the close of the seventeenth century, alludes as to a well-known fact.* The preposterous theories, therefore, that have been advanced in order to dispense with the elevation of the land, in the face of all this historical and physical evidence, are not entitled to a serious refutation.

Encroachments of the sea in the Bay of Baiæ.—The

* Vol. i. p. 50.

flat land, when first upraised, must have been more extensive than now, for the sea encroaches somewhat rapidly, both to the north and south-east of Puzzuoli. The coast has, of late years, given way more than a foot in a twelvemonth; and I was assured, by fishermen in the bay, that it has lost ground near Puzzuoli, to the extent of thirty feet, within their memory. It is, probably, this gradual encroachment, which has led many authors to imagine that the level of the sea is slowly rising in the Bay of Baiæ; an opinion by no means warranted by such circumstances. In the course of time, the whole of the low land will, perhaps, be carried away, unless some earthquake shall remodify the surface of the country, before the waves reach the ancient coast-line; but the removal of this narrow tract will by no means restore the country to its former state, for the old tufaceous hills, and the interstratified current of trachytic lava which has flowed from the Solfatara, must have participated in the movement of 1538; and these will remain upraised, even though the sea may regain its ancient limits.

In 1828, excavations were made below the marble pavement of the Temple of Serapis, and another costly pavement of mosaic was found, at the depth of five feet or more below the other. The existence of these two pavements, at different levels, seems clearly to imply some subsidence previously to all the changes already alluded to, which had rendered it necessary to construct a new floor at a higher level. But to these and other circumstances bearing on the history of the Temple antecedently to the revolutions already explained, I shall not refer at present, trusting that future investigations will set them in a clearer light.

Permanence of the ocean's level.—In concluding this subject, I may observe, that the interminable controversies to which the phenomena of the Bay of Baiæ gave rise, have sprung from an extreme reluctance to admit that the land, rather than the sea, is subject alternately to rise and fall. Had it been assumed that the level of the ocean was invariable, on the ground that no fluctuations have as yet been clearly established, and that, on the other hand, the continents are inconstant in their level, as has been demonstrated by the most unequivocal proofs again and again, from the time of Strabo to our own times, the appearances of the Temple at Puzzuoli could never have been regarded as enigmatical. Even if contemporary accounts had not distinctly attested the upraising of the coast, this explanation should have been proposed in the first instance as the most natural, instead of being now adopted unwillingly when all others have failed.

To the strong prejudices still existing in regard to the mobility of the land, we may attribute the rarity of such discoveries as have been recently brought to light in the Bay of Baiæ and the Bay of Conception. A false theory, it is well known, may render us blind to facts which are opposed to our prepossessions, or may conceal from us their true import when we behold them. But it is time that the geologist should, in some degree, overcome those first and natural impressions which induced the poets of old to select the rock as the emblem of firmness—the sea as the image of inconstancy. Our modern poet, in a more philosophical spirit, saw in the sea "The image of Eternity," and has finely contrasted the fleeting existence of the

successive empires which have flourished and fallen on the borders of the ocean with its own unchanged stability.

> ——— Their decay
> Has dried up realms to deserts : — not so thou,
> Unchangeable, save to thy wild waves' play :
> Time writes no wrinkle on thine azure brow ;
> Such as creation's dawn beheld, thou rollest now.
>
> Childe Harold, Canto iv.

CHAPTER XVII.

ELEVATION AND SUBSIDENCE OF LAND WITHOUT EARTHQUAKES.

Changes in the relative level of land and sea in regions not volcanic — Opinion of Celsius that the waters of the Baltic Sea and Northern Ocean were sinking — Objections raised to his opinion — Proofs of the stability of the sea-level in the Baltic — Playfair's hypothesis that the land was rising in Sweden — Opinion of Von Buch (p. 336.) — Marks cut on the rocks — Survey of these in 1820 — Facility of detecting slight alterations in level of sea on coast of Sweden — Shores of the ocean also rising — Area upheaved (p. 341.) — Shelly deposits of Uddevalla — Of Stockholm, containing fossil shells characteristic of the Baltic — Whether subsidence in Sweden — Fishing-hut buried under marine strata (p. 347.) — Sinking of land in Greenland — Bearing of these facts on geological phenomena.

We have now considered the phenomena of volcanos and earthquakes according to the division of the subject before proposed (p. 92.), and have next to turn our attention to those slow and insensible changes in the relative level of land and sea which take place in countries remote from volcanos, and where no violent earthquakes have occurred within the period of human observation. Early in the last century the Swedish naturalist, Celsius, expressed his opinion that the waters, both of the Baltic and Northern Ocean, were gradually subsiding. From numerous observations he

inferred, that the rate of depression was about forty Swedish inches in a century.* In support of this position, he alleged that there were many rocks both on the shores of the Baltic and the ocean known to have been once sunken reefs, and dangerous to navigators, but which were in his time above water — that the waters of the Gulf of Bothnia had been gradually converted into land, several ancient ports having been changed into inland cities, small islands joined to the continent, and old fishing grounds deserted as being too shallow, or entirely dried up. Celsius also maintained, that the evidence of the change rested not only on modern observations, but on the authority of the ancient geographers, who had stated that Scandinavia was formerly an island. This island, he argued, must in the course of centuries by the gradual retreat of the sea have become connected with the continent; an event which he supposed to have happened after the time of Pliny, and before the ninth century of our era.

To this argument it was objected that the ancients were so ignorant of the geography of the most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked, that if the land which connected Scandinavia with the main continent was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have risen above the sea at the latter pe-

* The Swedish measure scarcely differs from ours; the foot being divided into twelve inches, and being less than ours by three-eighths of an inch only.

riod, the rate of depression could not have been uniform, as was pretended; for it ought to have fallen much more rapidly between the ninth and eighteenth centuries.

Many of the proofs relied on by Celsius and his followers were immediately controverted by several philosophers, who saw clearly that a fall of the sea in any one region could not take place without a general sinking of the waters over the whole globe; they denied that this was the fact, or that the depression was universal, even in the Baltic. In proof of the stability of the level of that sea, they appealed to the position of the island of Saltholm, not far from Copenhagen. This island is so low that, in autumn and winter, it is permanently overflowed; and it is only dry in summer, when it serves for pasturing cattle. It appears from documents of the year 1280, that Saltholm was then also in the same state, and exactly on a level with the mean height of the sea, instead of having been about twenty feet under water, as it ought to have been, according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after six and even eight hundred years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level of the sea in the year 1000; and after eight centuries its relative position remains exactly the same.*

Several of the examples of the gain of land and shallowing of the sea pointed out by Celsius, and afterwards by Linnæus, who embraced the same opinions, were ascribed by others to the deposition of

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, Geschichte, &c. vol. i. p. 439.

sediment at points where rivers entered: and, undoubtedly, Celsius had not sufficiently distinguished between changes due to these causes, and such as would arise if the waters of the ocean itself were diminishing. Many large rivers descending from a mountainous country, at the head of the Gulf of Bothnia, enter the sea charged with sand, mud, and pebbles, and it was said that in these places the low land had advanced rapidly, especially near Torneo. At Piteo also, half a mile had been gained in forty-five years; at Luleo *, no less than a mile in twenty-eight years; facts which might all be admitted consistently with the assumption that the level of the Baltic has remained unchanged, like that of the Adriatic, during a period when the plains of the Po and the Adige have greatly extended their area.

It was also alleged that certain insular rocks, once entirely covered with water, had at length protruded themselves above the waves, and grown, in the course of a century and a half, to be eight feet high. The following attempt was made to explain away this phenomenon:— In the Baltic, large erratic blocks, as well as sand and smaller stones which lie on shoals, are liable every year to be frozen into the ice, where the sea freezes to the depth of five or six feet. On the melting of the snow in spring, when the sea rises about half a fathom, numerous ice-islands float away, bearing up these rocky fragments so as to convey them to a distance; and if they are driven by the waves upon shoals, they may convert them into islands by depositing the blocks; if stranded upon low islands, they may considerably augment their height.

* Piteo, Luleo, and Obo are spelt, in many English maps, Pitea, Lulea, Abo; but the *a* is not sounded in the Swedish diphthong *ao* or *å*.

Browallius, also, and some other Swedish naturalists, affirmed that some islands were lower than formerly; and that, by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious proof of the permanency of the water-level, at some points at least, for many centuries. On the Finland coast were some large pines, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that they had stood there for four hundred years. Now, according to the Celsian hypothesis, the sea had sunk about fifteen feet during that period, in which case the germination and early growth of these pines must have been, for many seasons, below the level of the water. In like manner it was asserted, that the lower walls of many ancient castles, such as those of Sonderburg and Åbo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea.

In reply to this last argument, Colonel Hällstrom, a Swedish engineer, well acquainted with the Finland coast, assured me, that the base of the walls of the castle of Åbo is now ten feet above the water, so that there may have been a considerable rise of the land at that point since the building was erected.

Playfair, in his "Illustrations of the Huttonian Theory," in 1802, admitted the sufficiency of the proofs adduced by Celsius, but attributed the change of level to the movement of the land, rather than to a diminution of the waters. He observed, "that in order to depress or elevate the absolute level of the sea, by a

given quantity, in any one place, we must depress or elevate it by the same quantity over the whole surface of the earth; whereas no such necessity exists with respect to the elevation or depression of the land."* The hypothesis of the rising of the land, he adds, "agrees well with the Huttonian theory, which holds that our continents are subject to be acted upon by the expansive forces of the mineral regions; that by these forces they have been actually raised up, and are sustained by them in their present situation." †

In the year 1807, Von Buch, after returning from a tour in Scandinavia, announced his conviction, "that the whole country, from Frederickshall in Sweden to Åbo in Finland, and perhaps as far as St. Petersburgh, was slowly and insensibly rising"—a conclusion to which he appears to have been led principally by information obtained from the inhabitants, and in part by the occurrence of marine shells of recent species, which he had found at several points on the coast of Norway above the level of the sea.

The attention excited by this subject in the early part of the last century, induced many philosophers in Sweden to endeavour to determine, by accurate observations, whether the standard level of the Baltic was really subject to periodical variations; and under their direction, lines or grooves, indicating the ordinary level of the water on a calm day, together with the date of the year, were chiselled out upon the rocks. In 1820-21, all the marks made before those years were examined by the officers of the pilotage establishment of Sweden; and in their report to the Royal Academy of Stockholm they declared, that on comparing the level of the sea at the time of their

* Sect. 393. † Sect. 398.

observations with that indicated by the ancient marks, they found that the Baltic was lower relatively to the land in certain places, but the amount of change during equal periods of time had not been every where the same. During their survey, they cut new marks for the guidance of future observers, several of which I had an opportunity of examining fourteen years after (in the summer of 1834), and in that interval the land appeared to me to have risen at certain places north of Stockholm four or five inches. I also convinced myself, during my visit to Sweden, after conversing with many civil engineers, pilots, and fishermen, and after examining some of the ancient marks, that the evidence formerly adduced in favour of the change of level, both on the coasts of Sweden and Finland, was full and satisfactory.* The alteration of level evidently diminishes as we proceed from the northern parts of the Gulf of Bothnia towards the south, being slight around Stockholm, and not in the least degree perceptible in Scania, the southernmost province of Sweden. Some writers have indeed represented the rate of depression of the waters at Stockholm as very considerable, because certain houses in that city which are built on piles have sunk down within the memory of persons still living, so as to be out of the perpendicular; and this in consequence of the tops of the piles giving way, and decaying, owing to a fall of the waters which has exposed them to be alternately wet and dry. The houses alluded to are situated on the

* In former editions I expressed many doubts as to the validity of the proofs of a gradual rise of land in Sweden. A detailed statement of the observations which I made in 1834, and which led me to change my opinion, will be found in the Philosophical Transactions for 1835, part i.

borders of Lake Maeler, a large lake, the outlet of which joins the Baltic in the middle of Stockholm. This lake is certainly lower than formerly; but the principal cause of the change is not the elevation of the land, but the removal of two old bridges built on piles, which formerly obstructed the discharge of the fresh-water into the sea. Another cause is the opening, in the year 1819, of a new canal at Södertelje, a place south of Stockholm, by means of which a new line of communication was formed between Lake Maeler and the Baltic.*

It will naturally be asked, whether the mean level of a sea like the Baltic can ever be determined so exactly as to permit us to appreciate a variation of level, amounting only to one or two feet. In reply, I may observe, that, except near the Cattegat, there are no tides in the Baltic; and it is only when particular winds have prevailed for several days in succession, or at certain seasons when there has been an unusually abundant influx of river water, or when these causes have combined, that this sea is made to rise two or three feet above its standard level. The fluctuations due to these causes are nearly the same from year to year; so that the pilots and fishermen believe, and apparently with reason, that they can mark a deviation, even of a few inches, from the ordinary or mean height of the waters.

There are, moreover, peculiarities in the configuration of the shores of Norway and Sweden, which facilitate, in a remarkable degree, the appreciation of slight changes in the relative level of land and water.

* See Professor Johnston's Paper, Ed. New Phil. Journ., No. XXIX., July 1833, and my remarks, Phil. Trans., 1835, p. 12.

It has often been said, that there are two coasts, an inner and an outer one; the inner being the shore of the mainland; the outer one, a fringe of countless rocky islands of all dimensions, called the skär (*shair*). Boats and small vessels make their coasting voyages within this skär; for here they may sail in smooth water, even when the sea without is strongly agitated. But the navigation is very intricate, and the pilot must possess a perfect acquaintance with the breadth and depth of every narrow channel, and the position of innumerable sunken rocks. If on such a coast the land rises one or two feet in the course of half a century, the minute topography of the skär is entirely altered. To a stranger, indeed, who revisits it after an interval of many years, its general aspect remains the same; but the inhabitant finds that he can no longer penetrate with his boat through channels where he formerly passed; and he can tell of countless other changes in the height and breadth of isolated rocks, now exposed, but once only seen through the clear water.

The rocks of gneiss, mica-schist, and quartz, are usually very hard on this coast, slow to decompose, and, when protected from the breakers, remaining for ages unaltered in their form. Hence it is easy to mark the stages of their progressive emergence by the aid of natural and artificial marks imprinted on them. Besides the summits of *fixed* rocks, there are numerous erratic blocks of vast size strewed over the shoals and islands in the skär, which have been probably drifted by ice in the manner before suggested.* All these are observed to have increased in height and dimen-

* See p. 334.; also Vol. I. p. 267.

sions within the last half century. Some, which were formerly known as dangerous sunken rocks, are now only hidden at high water. On their first appearance, they usually present a smooth, bare, rounded protuberance, a few feet or yards in diameter; and a single sea-gull often appropriates to itself this resting-place, resorting there to devour its prey. Similar points, in the mean time, have grown to long reefs, and are constantly whitened by a multitude of sea fowl; while others have been changed from a reef, annually submerged, to a small islet, on which a few lichens, a fir-seedling, and a few blades of grass, attest that the shoal has at length been fairly changed into dry land. Thousands of wooded islands around show the greater alterations which time can work. In the course of centuries also, the spaces intervening between the existing islands may be laid dry, and become grassy plains encircled by heights well clothed with lofty firs. This last step of the process, by which long fiords and narrow channels, once separating wooded islands, are deserted by the sea, has been exemplified within the memory of living witnesses on several parts of the coast.

Had the apparent fall of the waters been observed in the Baltic only, we might have endeavoured to explain the phenomenon by local causes affecting that sea alone. For instance, the channel by which the Baltic discharges its surplus waters into the Atlantic, might be supposed to have been gradually widened and deepened by the waves and currents, in which case a fall of the water, like that before alluded to in Lake Maeler, might have occurred. But the lowering of level would in that case have been uniform and universal, and the waters could not have sunk at Torneo, while they retained their former level at

Copenhagen. Such an explanation is also untenable on other grounds; for it is a fact, as Celsius long ago affirmed, that the alteration of level extends to the western shores of Sweden, bordering the ocean. The signs of elevation observed between Uddevalla and Gothenburg are as well established as those on the shores of the Bothnian Gulf. Among the places where they may be studied, are the islands of Marstrand and Gulholmen, the last-mentioned locality being one of those particularly pointed out by Celsius.

The inhabitants there and elsewhere affirm, that the rate of the sinking of the sea (or elevation of land) varies in different and adjoining districts, being greatest at points where the coast is low. But in this they are deceived; for they measure the amount of rise by the area gained, which is most considerable where the land descends with a gentle slope into the sea. In the same manner, some advocates of the Celsian theory formerly appealed to the increase of lands near the mouths of rivers, not sufficiently adverting to the fact, that if the bed of the sea is rising, the change will always be most sensible where the bottom has been previously rendered shallow; whereas, at a distance from these points, where the scarped granitic cliffs plunge at once into deep water, a much greater amount of elevation is necessary to produce an equally conspicuous change.

As to the area in northern Europe which is subject to this slow upheaving movement, we have not as yet sufficient data for estimating it correctly. It seems probable, however, that it reaches from Gothenburg to Torneo, and from thence to the North Cape, the rate of elevation increasing always as we proceed farther northwards. The two extremities of this line are

more than a thousand geographical miles distant from each other; and as both terminate in the ocean, we know not how much farther the motion may be prolonged under water. As to the breadth of the tract, its limits are equally uncertain, though it evidently extends across the widest parts of the Gulf of Bothnia, and may probably stretch far into the interior, both of Sweden and Finland. Now, if the elevation continue, a larger part of the Gulf of Bothnia will be turned into land, as also more of the ocean off the west coast of Sweden between Gothenburg and Uddevalla; and, on the other hand, if the change has been going on for thousands of years at the rate of several feet in a century, large tracts of what is now land must have been submarine at periods comparatively modern. It is natural therefore to inquire whether there are any signs of the recent sojourn of the sea on districts now inland? The answer is most satisfactory.— Near Uddevalla and the neighbouring coastland, we find upraised deposits of shells belonging to species such as now live in the ocean; while on the opposite or eastern side of Sweden, near Stockholm, Gefle, and other places bordering the Bothnian Gulf, there are analogous beds containing shells of species characteristic of the Baltic.

Von Buch announced, in 1807, that he had discovered in Norway and at Uddevalla in Sweden, beds of shells of existing species, at considerable heights above the sea. Since that time, other naturalists have confirmed his observation; and, according to Ström, deposits occur at an elevation of more than 400 feet above the sea in the northern part of Norway. M. Alex. Brongniart, when he visited Uddevalla, ascertained that one of the principal masses of shells, that of Capellbacken, is

raised more than 200 feet above the sea, resting on rocks of gneiss, all the species being identical with those now inhabiting the contiguous ocean. The same naturalist also stated that on examining with care the surface of the gneiss, immediately above the ancient shelly deposit, he found barnacles (*balani*) adhering to the rocks, showing that the sea had remained there for a long time. I was fortunate enough to be able to verify this observation by finding, in the summer of 1834, at Kured, about two miles north of Uddevalla, and at the height of more than 100 feet above the sea, a surface of gneiss newly laid open by the partial removal of a mass of shells used largely in the district for making lime and repairing the roads. So firmly did these barnacles adhere to the gneiss that I broke off portions of the rock with the shells attached. The face of the gneiss was also encrusted with small zoophytes (*Cellepora?* Lam.), but had these or the barnacles been exposed in the atmosphere ever since the elevation of the rocks above the sea, they would probably have decomposed and been obliterated.

The town of Uddevalla stands at the head of a narrow creek overhung by steep and barren rocks of gneiss, of which all the adjacent country is composed, except in the low grounds and bottoms of valleys where strata of sand, clay, and marl frequently hide the fundamental rocks. To these newer and horizontal deposits the fossil shells above mentioned belong, and similar marine remains are found at various heights above the sea on the opposite island of Orust. The extreme distance from the sea to which such fossils extend is as yet unknown, but they have been already found at Trollhättan in digging the canal there, and still farther inland on the northern borders of Lake

Wener fifty miles from the sea, at an elevation of 200 feet, near Lake Rogvarpen.

To pass to the Baltic: I observed near its shores at Södertelje, sixteen miles S. W. of Stockholm, strata of sand, clay, and marl, more than 100 feet high, and containing shells of species now inhabiting the Bothnian Gulf. These consist partly of marine and partly of freshwater species; but they are few in number, the brackishness of the water appearing to be very unfavourable to the development of testacea. The most abundant species are the common cockle, and the common mussel and periwinkle of our shores (*Cardium edule, Mytilus edulis, and Littorina littorea*), together with a small tellina (*T. Baltica*), and a few minute univalves allied to *Paludina ulva.* These live in the same waters as a *Lymneus*, a *Neritina* (*N. fluviatilis*), and some other freshwater shells.

But the marine molluscs of the Baltic above mentioned, although very numerous in individuals, are dwarfish in size, scarcely ever attaining a third of the average dimensions which they acquire in the salter waters of the ocean. By this character alone a geologist would generally be able to recognize an assemblage of Baltic fossils as distinguished from those derived from a deposit in the ocean. The absence also of oysters, barnacles, whelks, scallops, limpets (*ostrea, balanus, buccinum, pecten, patella*), and many other forms abounding alike in the sea near Uddevalla, and in the fossiliferous deposits of modern date on that coast, supplies an additional negative character of the greatest value, distinguishing assemblages of Baltic from those of oceanic shells. Now the strata containing Baltic shells are found in many localities near Stockholm, Upsala, and Gefle, and will probably be discovered every where

around the borders of the Bothnian Gulf; for I have seen similar remains brought from Finland, in marl resembling that found near Stockholm. The utmost distance to which these deposits have yet been traced inland, is on the southern shores of Lake Maeler, at a place seventy miles from the sea.*

As no accurate observations on the rise of the Swedish coast refer to periods more remote than a century and a half from the present time, and as traditional information, and that derived from ancient buildings on the coast, do not enable the antiquary to trace back any monuments of change for more than five or six centuries, we cannot declare whether the rate of the upheaving force is uniform during very long periods. In those districts where the fossil shells are found at the height of more than 200 feet above the ocean, as at Uddevalla, Orust, and Lake Rogvarpen, the present rate of rise seems less than four feet in a century. Even at that rate it would have required five thousand years to lift up those deposits. But as the movement is now very different in different places, it may also have varied much in intensity at different periods.

Whether any of the land in Norway is now rising must be determined by future investigations. Marine fossil shells, of recent species, have been collected from inland places near Drontheim; but Mr. Everest, in his "Travels through Norway," informs us that the small island of Munkholm, which is an insulated rock in the harbour of Drontheim, affords conclusive evidence of the land having in that region remained stationary for the last eight centuries. The area of this isle does not exceed that of a small village,

* Phil. Trans., 1835, part i.

and by an official survey, its highest point has been determined to be twenty-three feet above the mean high water mark, that is, the mean between neap and spring tides. Now, a monastery was founded there by Canute the Great, A.D. 1028, and thirty-three years before that time it was in use as a common place of execution. According to the assumed average rate of rise in Sweden (about forty inches in a century), we should be obliged to suppose that this island had been three feet eight inches below high water mark when it was originally chosen as the site of the monastery.

But we have not only to learn whether the motion proceeds always at the same rate, but also whether it has been uniformly *in one direction.* The level of the land may oscillate; and for centuries there may be a depression, and afterwards a re-elevation, of the same district. This idea is rendered the more probable by the observations of MM. Pingel and Graah, Danish travellers, who visited Greenland in 1830-32; for they are convinced that part of the coast of Greenland has been sinking down during the last four centuries, throughout a space extending for about four hundred geographical miles in length; and in consequence of this subsidence the habitations of the Esquimaux, and of the early Danish colonists, are now submerged at high water.*

Some phenomena in the neighbourhood of Stockholm, appear to me only explicable on the supposition of the alternate rising and sinking of the ground since the country was inhabited by man. In digging a canal,

* A detailed account of these researches will shortly be published. The information was communicated to me at Copenhagen by M. Pingel, in 1834.

in 1819, at Södertelje, about sixteen miles to the south of Stockholm, to unite Lake Maeler with the Baltic, marine strata, containing fossil shells of Baltic species, were passed through. At a depth of about sixty feet, they came down upon what seems to have been a buried fishing-hut, constructed of wood, in a state of decomposition, which soon crumbled away on exposure to the air. The lowest part, however, which had stood on a level with the sea, was in a more perfect state of preservation. On the floor of this hut was a rude fireplace, consisting of a ring of stones, and within this were cinders and charred wood. On the outside lay boughs of the fir, cut as with an axe, with the leaves or needles still attached. It seems impossible to explain the position of this buried hut, without imagining, as in the case of the Temple of Serapis (see p. 312.), first, a subsidence to the depth of more than sixty feet, then a re-elevation. During the period of submergence, the hut must have become covered over with gravel and shelly marl, under which not only the hut, but several vessels also were found, of a very antique form, and having their timbers fastened together by wooden pegs instead of nails.*

The probable cause of these movements, whether of elevation or depression, will be more appropriately discussed in the following chapters, when the origin of subterranean heat is considered. But I may remark here, that the rise of Scandinavia has naturally been regarded as a very singular and scarcely credible phenomenon, because no region on the globe has been more free within the times of authentic history from violent earthquakes. In common, indeed, with our

* See the paper before referred to, Phil. Trans., 1835, pt. i.

own island, and with almost every spot on the globe, some movements have been, at different periods, experienced, both in Norway and Sweden, as during the earthquake of Lisbon, and on a few other occasions. There have also been some recent shocks in Sweden, as in England, sufficiently local to indicate a source of disturbance immediately under the country itself, and not merely a tremor produced by the lateral prolongation of movements from great distances. Notwithstanding these shocks Scandinavia has, upon the whole, been as tranquil in modern times, and as free from subterranean convulsions, as any region of equal extent on the globe. There is also another circumstance, which has made the change of level in Sweden appear anomalous, and has for a long time caused the proofs of the fact to be received with reluctance. Volcanic action, as we have seen, is usually intermittent; and the variations of level to which it has given rise have taken place by starts, not by a prolonged and insensible movement similar to that experienced in Sweden.

Yet, when we are once assured of the reality of the gradual rise of a large region, it enables us to account for many geological appearances otherwise very difficult of explanation. There are large continental tracts and high table lands where the strata are nearly horizontal, bearing no marks of having been thrown up by violent convulsions, nor by a series of movements, such as those which occur in the Andes, and cause the earth to be rent open, and raised or depressed from time to time, while masses are engulphed in subterranean cavities. The result of a series of such earthquakes might be to produce in a great lapse of ages a country of shattered, inclined, and perhaps vertical strata. But a movement like that of Scandinavia would cause the

bed of the sea, and all the strata recently formed in it, to be upheaved so gradually, that it would merely seem as if the ocean had formerly stood at a higher level, and had slowly and tranquilly sunk down into its present bed.

The fact also of a very gradual and insensible elevation of land may explain many geological monuments of denudation, on a grand scale. If, for example, instead of the hard granitic rocks of Norway and Sweden, a large part of the bed of the Atlantic, consisting chiefly of soft strata, should rise up, century after century, at the rate of about half an inch, or an inch, in a year, how easily might oceanic currents, such as those described in the sixth chapter, sweep away the thin film of matter thus brought up annually within the sphere of aqueous denudation! The tract, when it finally emerged, might present table lands and ridges of horizontal strata, with intervening valleys and vast plains, where originally, and during its period of submergence, the surface may have been level and nearly uniform.

These speculations relate to superficial changes; but others must be continually in progress in the subterranean regions. The foundations of the country, thus gradually uplifted in Sweden, must be undergoing important modifications. Whether we ascribe these to the expansion of solid matter by continually increasing heat, or to the liquefaction of rock, or to the crystallization of a dense fluid, or the accumulation of pent-up gases, in whatever conjectures we indulge, we can never doubt for a moment, that at some unknown depth the structure of the globe is in our own times becoming changed from day to day, throughout a space probably more than a thousand miles in length, and several hundred in breadth.

CHAPTER XVIII.

CAUSES OF EARTHQUAKES AND VOLCANOS.

Intimate connexion between the causes of volcanos and earthquakes — Supposed original state of fusion of the planet — Universal fluidity not proved by spheroidal figure of the earth — Heat in mines increasing with the depth (p. 356.) — Objections to the supposed intense heat of a central fluid — Whether chemical changes may produce volcanic heat (p. 363.) — Currents of electricity circulating in the earth's crust — Theory of an unoxidated metallic nucleus (p. 370.) — The metallic oxides when heated may be deoxidated by hydrogen.

It will hardly be questioned, after the description before given of the phenomena of earthquakes and volcanos, that both of these agents have, to a certain extent, a common origin; and I may now, therefore, proceed to inquire into their probable causes. But first, it may be well to recapitulate some of those points of relation and analogy which lead naturally to the conclusion, that they spring from a common source.

The regions convulsed by violent earthquakes include within them the site of all the active volcanos. Earthquakes, sometimes local, sometimes extending over vast areas, often precede volcanic eruptions. The subterranean movement and the eruption return again and again, at irregular intervals of time, and with unequal degrees of force, to the same spots. The

action of either may continue for a few hours, or for several consecutive years. Paroxysmal convulsions are usually followed, in both cases, by long periods of tranquillity. Thermal and mineral springs are abundant in countries of earthquakes and active volcanos. Lastly, hot springs situated in districts considerably distant from volcanic vents have been observed to have their temperature suddenly raised, and the volume of their water augmented, by subterranean movements.

All these appearances are evidently more or less connected with the passage of heat from the interior of the earth to the surface; and where there are active volcanos, there must exist, at some unknown depth below, enormous masses of matter intensely heated, and, in many instances, in a constant state of fusion. We have first, then, to inquire, whence is this heat derived?

It has long been a favourite conjecture, that the whole of our planet was originally in a state of igneous fusion, and that the central parts still retain a great portion of their primitive heat. Some have imagined, with the late Sir W. Herschel, that the elementary matter of the earth may have been first in a gaseous state, resembling those nebulæ which we behold in the heavens, and which are of dimensions so vast, that some of them would fill the orbits of the remotest planets of our system. It is conjectured that such aëriform matter (for in many cases the nebulous appearance cannot be referred to clusters of very distant stars), if concentrated, might form solid spheres; and others have imagined that the evolution of heat, attendant on condensation, might retain the materials of the new globes in a state of igneous fusion.

Without dwelling on such speculations, which can never have any direct bearing on geology, we may consider how far the spheroidal form of the earth affords sufficient ground for presuming that its primitive condition was one of universal fluidity. The discussion of this question would be superfluous, were the doctrine of original fluidity less popular; for it may well be asked, why the globe should be supposed to have had a pristine shape different from the present one?—why the terrestrial materials, when first called into existence, or assembled together in one place, should not have been subject to rotation, so as to assume at once that form which alone could retain their several parts in a state of equilibrium?

Let us, however, concede that the statical figure may be a modification of some other pre-existing form, and suppose the globe to have been at first a perfect and quiescent sphere, covered with an uniform ocean —what would happen when it was made to turn round on its axis with its present velocity? "A centrifugal force," says Sir J. Herschel, "would in that case be generated, whose general tendency would be to urge the water at every point of the surface to *recede* from the *axis*. A rotation might indeed be conceived so swift as to flirt the whole ocean from the surface, like water from a mop. But this would require a far greater velocity than what we now speak of. In the case supposed, the *weight* of the water would still keep it *on* the earth; and the tendency to recede from the axis *could* only be satisfied, therefore, by the water leaving the poles, and flowing towards the equator; there heaping itself up in a ridge, and being retained in opposition to its weight or natural tendency towards the centre by the pressure thus caused. This, how-

ever, could not take place without laying dry the polar regions, so that protuberant land would appear at the poles, and a zone of ocean be disposed around the equator. This would be the first or immediate effect. Let us now see what would afterwards happen if things were allowed to take their natural course.

"The sea is constantly beating on the land, grinding it down, and scattering its worn-off particles and fragments, in the state of sand and pebbles, over its bed. Geological facts afford abundant proof that the existing continents have all of them undergone this process, even more than once, and been entirely torn in fragments, or reduced to powder, and submerged and reconstructed. Land, in this view of the subject, loses its attribute of fixity. As a mass it might hold together in opposition to forces which the water freely obeys; but in its state of successive or simultaneous degradation, when disseminated through the water, in the state of sand or mud, it is subject to all the impulses of that fluid. In the lapse of time, then, the protuberant land would be destroyed, and spread over the bottom of the ocean, filling up the lower parts, and tending continually to re-model the surface of the solid nucleus, in correspondence with the *form of equilibrium*. Thus after a sufficient lapse of time, in the case of an earth in rotation the polar protuberances would gradually be cut down and disappear, being transferred to the equator (as being *then* the *deepest sea*), till the earth would assume by degrees the form we observe it to have — that of a flattened or *oblate* ellipsoid.

"We are far from meaning here to trace the process *by which* the earth really assumed its actual form; all

we intend is to show that this is the form to which, under a condition of a rotation on its axis, it must *tend*, and which it would attain even if originally and (so to speak) perversely constituted otherwise." *

In this passage, the author of the "Discourse on the Study of Natural Philosophy" has contemplated the superficial effects of aqueous causes only; he might have added that every stream of lava which flowed out of a volcano would be impelled, in a slight degree, towards the equatorial regions, in obedience to the same power; and if the volcanic action should extend to great depths, so as to melt, one after another, different parts of the earth, the whole interior might at length be remodelled under the influence of similar changes, due to causes which may all be operating at this moment. The statical figure, therefore, of the terrestrial spheriod (of which the longest diameter exceeds the shortest by about twenty-five miles), may have been the result of gradual and even of existing causes, and not of a primitive, universal, and simultaneous fluidity.

Experiments made with the pendulum, and observations on the manner in which the earth attracts the moon, have shewn that our planet is not an empty sphere, but that it must rather increase in density from the surface towards the centre; and it has also been inferred that the equatorial protuberance is continued inwards, that is to say, that layers of equal density are arranged elliptically, and symmetrically, from the exterior to the centre. The inequalities, however, in the moon's motion, on which this opinion

* Herschel's Astronomy, chap. iii.

is founded, are so extremely slight, that it can be regarded as little more than a probable conjecture.

The mean density of the earth has been computed by Laplace to be about $5\frac{1}{2}$, or more than five times that of water. Now the specific gravity of many of our rocks is from $2\frac{1}{2}$ to 3, and the greater part of the metals range between that density and 21. Hence some have imagined that the terrestrial nucleus may be metallic — that it may correspond, for example, with the specific gravity of iron, which is about 7. But here a curious question arises in regard to the form which materials, whether fluid or solid, might assume, if subjected to the enormous pressure which must obtain at the earth's centre. Water, if it continued to decrease in volume according to the rate of compressibility deduced from experiment, would have its density doubled at the depth of ninety-three miles, and be as heavy as mercury at the depth of 362 miles. Dr. Young computed that, at the earth's centre, steel would be compressed into one-fourth, and stone into one-eighth of its bulk.* It is more than probable, however, that after a certain degree of condensation, the compressibility of bodies may be governed by laws altogether different from those which we can put to the test of experiment; but the limit is still undetermined, and the subject is involved in such obscurity, that we cannot wonder at the variety of notions which have been entertained respecting the nature and conditions of the central nucleus. Some have conceived it to be fluid, others solid; some have imagined it to have a cavernous structure, and have even endea-

* Young's Lectures, and Mrs. Somerville's Connexion of the Physical Sciences, p. 90.

voured to confirm this opinion by appealing to observed irregularities in the vibrations of the pendulum in certain countries.

Central Heat. — The hypothesis of internal fluidity calls for the more attentive consideration, as it has been found that the heat in mines augments in proportion as we descend. Observations have been made, not only on the temperature of the air in mines, but on that of the rocks, and on the water issuing from them. The mean rate of increase, calculated from results obtained in six of the deepest coal mines in Durham and Northumberland, is 1° Fahr. for a descent of forty-four English feet.* A series of observations, made in several of the principal lead and silver mines in Saxony, gave 1° Fahr. for every sixty-five feet. In this case, the bulb of the thermometer was introduced into cavities purposely cut in the solid rock at depths varying from two hundred to above nine hundred feet. But in other mines of the same country, it was necessary to descend thrice as far for each degree of temperature.†

A thermometer was fixed in the rock of the Dolcoath mine, in Cornwall, by Mr. Fox, at the great depth of 1380 feet, and frequently observed during eighteen months; the mean temperature was 68° Fahr., that of the surface being 50°, which gives 1° for every seventy-five feet.

Kupffer, after an extensive comparison of the results in different countries, makes the increase 1° F. for about every thirty-seven English feet‡; and Cordier considers that it would not be overstated at 1°

* Ed. Journal of Sci., April 1832.

† Cordier, Mém. de l'Instit., tom. vii.

‡ Pog. Ann. tom. xv. p. 159.

Cent. for every twenty-five metres, or about 1° F. for every forty-five feet.*

Some writers have endeavoured to refer these phenomena (which, however discordant as to the ratio of increasing heat, appear all to point one way), to the condensation of air constantly descending from the surface into the mines. For the air under pressure would give out latent heat, on the same principle as it becomes colder when rarified in the higher regions of the atmosphere. But, besides that the quantity of heat is greater than could be supposed to flow from this source, the argument has been answered in a satisfactory manner by Mr. Fox, who has shown, that in the mines of Cornwall the ascending have generally a higher temperature than the descending aërial currents. The difference between them was found to vary from 9° to 17° F.: a proof, that instead of imparting heat, these currents actually carry off a large quantity from the mines.†

If we adopt M. Cordier's estimate of 1° F. for every 45 feet of depth as the mean result, and assume, with the advocates of central fluidity, that the increasing temperature is continued downwards, we should reach the ordinary boiling point of water at about two miles below the surface, and at the depth of about twenty-four miles should arrive at the melting point of iron, a heat sufficient to fuse almost every known substance. The temperature of melted iron was estimated at 21,000° F., by Wedgwood; but his pyrometer gives, as is now demonstrated, very erroneous results. It

* Cordier, Mém. de l'Instit. tom. vii.

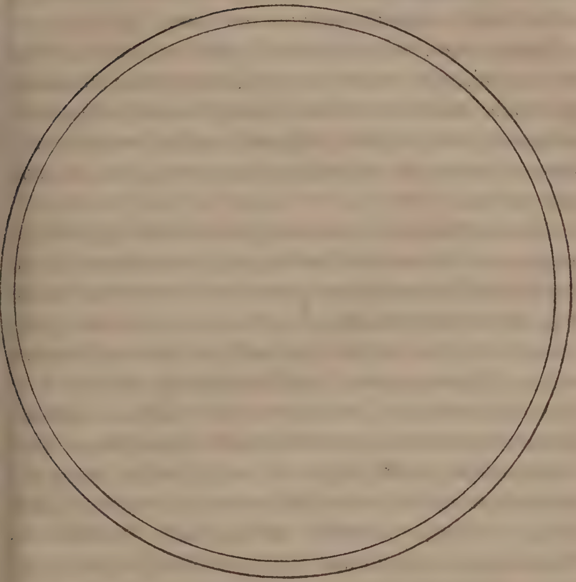
† Phil. Mag. and Ann., Feb. 1830.

has been ascertained by Professor Daniell, that the point of fusion is 2786° F.*

By adopting the least correct of these two results, the melting point of our ordinary rocks would be farther removed from the surface; but this difference does not affect the probability of the theory now under consideration. According to Mr. Daniell's scale, we ought to encounter the internal melted matter before penetrating through a thickness represented by that of the outer circle in the annexed diagram; whereas, if the other scale be correct, we should meet with it at some point between the two circles; the space between them, together with the lines themselves, representing a crust of two hundred miles in depth. In either case, we must be prepared to maintain, that a temperature many times greater than that sufficient to melt the most refractory substances known to us, is sustained at the centre of the globe; while a comparatively thin crust, resting upon the fluid, remains unmelted; or is even, according to M. Cordier, increasing in thickness, by the continual addition of new internal layers solidified during the process of refrigeration.

* The heat was measured in Wedgwood's pyrometer by the contraction of pure clay, which is reduced in volume when heated, first by the loss of its water of combination, and afterwards on the application of more intense heat, by incipient vitrification. The expansion of platina is the test employed by Mr. Daniell, in his pyrometer, and this has been found to yield uniform and consistent results, such as are in perfect harmony with conclusions drawn from various other independent sources. The instrument for which the author received the Rumford Medal from the Royal Society in 1833, is described in the Phil. Trans. 1830, part ii., and 1831, part ii.

Fig. 45.



Section of the earth in which the breadth of the outer boundary line reprcsents a thickness of 25 miles; the space between the circles including the breadth of the lines, 200 miles.

The mathematical calculations of Fourier, on the passage of heat through conducting bodies, have been since appealed to in support of these views; for he has shown that it is compatible with theory that the present temperature of the surface might coexist with an intense heat, at a certain depth below. But his reasoning seems to be confined to the conduction of heat through solid bodies; and the conditions of the problem are wholly altered when we reason about a fluid nucleus, as we must do, if it be assumed that the heat augments from the surface to the interior, according to the rate observed in mines. For when

the heat of the lower portion of a fluid is increased, a circulation begins throughout the mass, by the ascent of hotter, and the descent of colder currents. And this circulation, which is quite distinct from the mode in which heat is propagated through solid bodies, must evidently occur in the supposed central ocean, if the laws of fluids and of heat are the same there as upon the surface.

In Mr. Daniell's recent experiments for obtaining a measure of the heat of bodies, at their point of fusion, he invariably found that it was impossible to raise the heat of a large crucible of melted iron, gold, or silver, a single degree beyond the melting point, so long as a bar of the respective metals was kept immersed in the fluid portions. So in regard to other substances, however great the quantities fused, their temperature could not be raised while any solid pieces immersed in them remained unmelted; every accession of heat being instantly absorbed during their liquefaction. These results are, in fact, no more than the extension of a principle previously established, that so long as a fragment of ice remains in water, we cannot raise the temperature of the water above 32° F.

If, then, the heat of the earth's centre amount to 450,000° F., as M. Cordier deems highly probable, that is to say, about twenty times the heat of melted iron, even according to Wedgwood's scale, and upwards of 160 times according to the improved pyrometer, it is clear that the upper parts of the fluid mass could not long have a temperature only just sufficient to melt rocks. There must be a continual tendency towards a uniform heat; and until this were accomplished, by the interchange of portions of fluid of different densities, the surface could not begin to

consolidate. Nor, on the hypothesis of primitive fluidity, can we conceive any crust to have been formed until *the whole* planet had cooled down to about the temperature of incipient fusion.

It cannot be objected that hydrostatic pressure would prevent a tendency to equalization of temperature; for, as far as observations have yet been made, it is found that the waters of deep lakes and seas are governed by the same laws as a shallow pool; and no experiments indicate that solids resist fusion under high pressure. The arguments, indeed, now controverted, always proceed on the admission that the internal nucleus is in a state of fusion.

It may be said that we may stand upon the hardened surface of a lava current while it is still in motion,—nay, may descend into the crater of Vesuvius after an eruption, and stand on the scoriæ while every crevice shows that the rock is red-hot two or three feet below us; and at a somewhat greater depth, all is, perhaps, in a state of fusion. May not, then, a much more intense heat be expected at the depth of several hundred yards, or miles? The answer is,—that, until a great quantity of heat has been given off, either by the emission of lava, or in a latent form by the evolution of steam and gas, the melted matter continues to boil in the crater of a volcano. But ebullition ceases when there is no longer a sufficient supply of heat from below, and then a crust of lava may form on the top, and showers of scoriæ may then descend upon the surface, and remain unmelted. If the internal heat be raised again, ebullition will recommence, and soon fuse the superficial crust. So in the case of the moving current, we may safely assume that no part of the

liquid beneath the hardened surface is much above the temperature sufficient to retain it in a state of fluidity.

It may assist us in forming a clearer view of the doctrine now controverted, if we consider what would happen were a globe of homogeneous composition placed under circumstances analogous, in regard to the distribution of heat, to those above stated. If the whole planet, for example, were composed of water covered with a spheroidal crust of ice fifty miles thick, and with an interior ocean having a central heat about two hundred times that of the melting point of ice, or 6400° F.; and if, between the surface and the centre, there was every intermediate degree of temperature between that of melting ice and that of the central nucleus;—could such a state of things last for a moment? If it must be conceded, in this case, that the whole spheroid would be instantly in a state of violent ebullition, that the ice (instead of being strengthened annually by new internal layers) would soon melt, and form part of an atmosphere of steam—on what principle can it be maintained that analogous effects would not follow, in regard to the earth, under the conditions assumed in the theory of central heat?

M. Cordier admits that there must be tides in the internal melted ocean; but their effect, he says, has become feeble, although originally, when the fluidity of the globe was perfect, the rise and fall of these ancient land tides could not have been less than from thirteen to sixteen feet. Now granting, for a moment, that these tides have become so feeble as to be incapable of lifting up every six hours the fissured shell of the earth, may we not ask whether, during eruptions, jets of lava ought not to be thrown up from the craters

of volcanos, when the tides rise? — and whether the same phenomena would not be conspicuous in Stromboli, where there is always lava boiling in the crater? Ought not the fluid, if connected with the interior ocean, to disappear entirely on the ebbing of its tides?

Whether chemical changes may produce volcanic heat. — Having now explained the reasons which have induced me to reject the hypothesis of central heat as the primary source of volcanic action, it remains to consider what has been termed the chemical theory of volcanos. It is well known that many, perhaps all, of the substances of which the earth is composed are continually undergoing chemical changes. To what depth these processes may be continued downwards must, in a great degree, be matter of conjecture; but there is no reason to suspect that, if we could descend to a great distance from the surface, we should find elementary substances differing essentially from those with which we are acquainted.

Playfair has, indeed, attempted to deduce, from an observation of Pallas, that we can, by the aid of geology, see, as it were, into the interior thirty miles or more; for Pallas had described, in the peninsula of Tauris, a series of parallel strata as regular as the leaves of a book, inclined at an angle of 45° to the horizon, and exposed in a continuous section eighty-six English miles long. The height of the range of hills composed of these strata does not exceed twelve hundred feet; but if we measure the thickness of the stratified mass by a line perpendicular to its stratification, the height of the uppermost bed above the undermost must have been originally more than sixty miles; and, even allowing, says Playfair, that the strata had shifted during their elevation, we may still suppose

a thickness of thirty miles. But, if a deception to the extent of one half is allowed for, on the score of shifting, it may well be asked why the same cause might not have produced a much greater amount of error? I shall point out, in another place, that, besides the probability of a shifting of the beds during elevation, there may also have been an original deviation from horizontality in the strata, which might cause them to assume the appearance of having been deposited in an ocean many leagues in depth, when, in fact, they may have been accumulated in a sea only a few hundred fathoms deep.*

Nevertheless, since we discover in mountain chains strata thousands of feet thick, which must have been formed at the bottom of the sea, but are now raised to the height of four or five miles above it, we may fairly speculate on the probability of rocks, such as are now on the surface, existing at the depth of several leagues below.

We may next recall to mind that all the solid, fluid, and gaseous bodies which enter into the composition of the earth, consist of a very small number of elementary substances variously combined: the total number of elements at present known is less than sixty; and not half of these enter into the composition of the more abundant inorganic productions.

Some portions of the compounds above alluded to are daily resolved into their elements; and these, on being set free, are always passing into new combinations. These processes are by no means confined to the surface, and are almost always accompanied by the evolution of heat, which is intense in proportion to the

* Book iv. chap. xii.

rapidity of the combinations. At the same time, there is a development of electricity.

It is well known that mixtures of sulphur and iron, sunk in the ground, and exposed to moisture, give out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that are near. The following experiment was first made by Lemery:— Let a large quantity of clean iron filings be mixed with a still larger proportion of sulphur, and as much water as is necessary to make them into a firm paste. Let the mixture be then buried in the earth, and the soil pressed down firmly upon it. In a few hours it will grow warm, and swell so as to raise the ground; sulphureous vapours will make their way through the crevices, and sometimes flames appear. There is rarely an explosion; but, when this happens, the fire is vivid, and, if the quantity of materials is considerable, the heat and fire both continue for a long time.*

The spontaneous combustion of beds of bituminous shale, and of refuse coal thrown out of mines, is also generally due to the decomposition of pyrites; and it is the contact of water, not of air, which brings about the change. A smouldering heat results from the various new combinations, which immediately take place when the sulphur and other substances are set free. Similar effects are often produced in mines where no coaly matter is present, where substances capable of being decomposed by water are heaped together.

On what principle heat is generated, when two or more bodies having a strong affinity for each other unite suddenly, is wholly unexplained; but it is a singular fact that, while chemical combination causes

* Daubeny's Volcanos, p. 356.

heat, the disunion of elements does not produce the opposite effect, or a corresponding degree of cold. It may be said that decomposition is usually brought about by the combination of one or more of the elements with a new substance, and this concomitant agency might be supposed to neutralize or counterbalance any frigorific effects which might otherwise be sensible. But this explanation is, in many cases, wholly inapplicable; as, for example, when the voltaic pile is used for decomposition, or in the more striking instance of the well-known detonating powder, the iodine of nitrogen, which explodes with violence in the open air, the instant it is touched by a cold substance. The two elements into which this binary compound is resolved fly off in a gaseous form, and do not unite with any other body, the iodine rising in a purple vapour, while the nitrogen may be collected separately. Yet sudden as is the process by which their union is broken, we find that heat and light, instead of cold, are generated.

Electricity a source of volcanic heat.—It has already been stated, that chemical changes develope electricity; which, in its turn, becomes a powerful disturbing cause. As a chemical agent, says Davy, its silent and slow operation in the economy of nature is much more important than its grand and impressive operation in lightning and thunder. It may be considered, not only as directly producing an infinite variety of changes, but as influencing almost all which take place; it would seem, indeed, that chemical attraction itself is only a peculiar form of the exhibition of electrical attraction.*

* Consolations in Travel, p. 271.

Now that it has been demonstrated that magnetism and electricity are always associated, and are perhaps only different conditions of the same power, the phenomena of terrestrial magnetism have become of no ordinary interest to the geologist. Soon after the first great discoveries of Oersted in electro-magnetism, Ampere suggested that all the phenomena of the magnetic needle might be explained by supposing currents of electricity to circulate constantly in the shell of the globe in directions parallel to the magnetic equator. This theory has acquired additional consistency the farther we have advanced in science; and according to the experiments of Mr. Fox, on the electro-magnetic properties of metalliferous veins, some trace of electric currents seems to have been detected in the interior of the earth. *

Some philosophers ascribe these currents to the chemical action going on in the superficial parts of the globe to which air and water have the readiest access; while others refer them, in part at least, to thermo-electricity excited by the solar rays on the surface of the earth during its rotation; successive parts of the land and sea being exposed to the influence of the sun, and then cooled again in the night. That this idea is not a mere speculation, is proved by the correspondence of the diurnal variations of the magnet with the apparent motion of the sun; and by the greater amount of variation in summer than in winter, and during the day than in the night. M. de la Rive, although conceding that such minor variations of the needle may be due to thermo-electricity, contends that the general phenomena of terrestrial mag-

* Phil. Trans. 1830, p. 399.

netism must be attributed to currents far more intense; which, though liable to secular fluctuations, act with much greater constancy and regularity than the causes which produce the diurnal variations.* The remark seems just; yet it is difficult to assign limits to the accumulated influence even of a very feeble force constantly acting on the whole surface of the earth. This subject, however, must evidently remain obscure, until we become acquainted with the causes which give a determinate direction to the supposed electric currents. Already the experiments of Faraday on the rotation of magnets have led him to speculate on the manner in which the earth, when once it had become magnetic, might produce electric currents within itself, in consequence of its diurnal rotation.†

Before leaving the consideration of thermo-electricity, I may remark, that it may be generated by great inequalities of temperature, arising from a partial distribution of volcanic heat. Wherever, for example, masses of rock occur of great horizontal extent, and of considerable depth, which are, at one point in a state of fusion (as beneath some active volcano); at another, red hot; and at a third, comparatively cold — strong thermo-electric action may be excited.

Some, perhaps, may object, that this is reasoning in a circle; first to introduce electricity as one of the primary causes of volcanic heat, and then to derive the same heat from thermo-electric currents. But there must, in truth, be much reciprocal action between the agents now under consideration; and it is very difficult to decide which should be regarded as the

* Biblioth. Univers., 1833, Electricité.

† Phil. Trans., 1832, p. 176.; also pp. 172, 173, &c.

prime mover, or to see where the train of changes, once begun, would terminate.

In the ordinary operations of nature, it is in the atmosphere alone that we observe the action of electricity; and it is probable that a moment never passes without a flash of lightning striking some part of the earth. The electric fluid shatters rocks, and instantaneously melts substances which are commonly regarded as infusible. The air is supposed to derive a great part of this electricity directly from the earth *; and M. Necker seems to have succeeded in establishing that there is a connection between the direction of the curves of equal magnetic intensity and the *strike* of the principal mountain chains. † Some, also, attribute the electricity of the air to the evaporation of sea-water by the sun: for it can be shown, by experiment, that the conversion of salt water into vapour is accompanied by the excitement of electricity; and the process alluded to takes place on so vast a scale, — the measure of the quantity of evaporation being the constant flow of all the rivers of the earth, exclusive of the rain which falls directly into the ocean, — that a feeble action of this kind may become very powerful by accumulation.

During volcanic eruptions, vivid lightnings are almost invariably seen in the clouds of vapour which ascend from the crater; and, as there are always one or more eruptions going on in some part of the globe, we are here presented with another perpetual source of derangement. How far subterranean electric currents may possess the decomposing power of the voltaic pile,

* Faraday, Phil. Trans., 1832, p. 177.

† Bibliot. Univers., tom. xliii. p. 166.

is a question for those alone are who are farthest advanced in the career of discovery in a rapidly progressive science; but such a power would at once supply us with a never-failing source of chemical action, from which volcanic heat might be derived.

Theory of an unoxidated metallic nucleus. — When Sir H. Davy first discovered the metallic bases of the earths and alkalies, he threw out the idea that those metals might abound in an unoxidized state in the subterranean regions to which water must occasionally penetrate. Whenever this happened, gaseous matter would be set free, the metals would combine with the oxygen of the water, and sufficient heat might be evolved to melt the surrounding rocks. This hypothesis was at first very favourably received, both by the chemist and the geologist; for silica, alumina, lime, soda, and oxide of iron, — substances of which lavas are principally composed, — would all result from the contact of the inflammable metals alluded to with water. But whence this abundant store of unsaturated metals in the interior? It was assumed that, in the beginning of things, the nucleus of the earth was mainly composed of inflammable metals, and that oxidation went on with intense energy at first; till, at length, when a superficial crust of oxides had been formed, the chemical action became more and more languid.

It must be confessed, that this assumption was not less arbitrary than that first suggested by Leibnitz, of an original igneous fluid; for a particular mineral condition of a primitive solid nucleus is, to say the least, as bold a speculation as a newly created mass of incandescent matter. It would, perhaps, be more philosophical to begin by inquiring, whether any existing

causes may have the power of deoxidating the earthy and alkaline compounds formed from time to time by the action of water upon the metallic bases; so that the previous state of things might, under favourable circumstances, be restored, a permament chemical action sustained, and a continual circle of operation kept up. It has been suggested to me, by Mr. Daniell, that we have, in hydrogen, precisely such a deoxidating agent as would be required. It is well known to chemists, that the metallization of the most difficultly reduced oxides may be effected by hydrogen brought into contact with them at a red heat; and it is more than probable that the production of potassium itself, in the common gun-barrel process, is due to the power of nascent hydrogen derived from the water which the hydrated oxide contains. According to the recent experiments, also, of Faraday, it would appear that every case of metallic reduction by voltaic agency, from saline solutions, in which water is present, is due to the secondary action of hydrogen upon the oxide; both of these being determined to the negative pole, and then reacting upon one another.

It has never been disputed that intense heat might be produced by the occasional contact of water with the metallic bases; and it is quite certain that, during the process of saturation, vast volumes of hydrogen must be evolved. The hydrogen, thus generated, might permeate the crust of the earth in different directions, and be stored up for ages in fissures and caverns, sometimes in a liquid form, under the necessary pressure. Whenever, at any subsequent period, in consequence of the changes effected by earthquakes in the shell of the earth, this gas happened to come in contact

with metallic oxides at a high temperature, the reduction of these oxides would be the necessary result.

Recapitulation.—In the next chapter I shall inquire more particularly into the manner in which the phenomena of earthquakes and volcanos accord with the hypothesis of a continued generation of heat by chemical action. But, first, it may be desirable to recapitulate, in a few words, the conclusions already obtained.

1st. The primary causes of the volcano and the earthquake are, to a great extent, the same, and must be connected with the passage of heat from the interior to the surface.

2ndly. This heat has been referred, by many, to a supposed state of igneous fusion of the central parts of the planet when it was first created, of which a part still remains in the interior, but is always diminishing in intensity.

3dly. The spheroidal figure of the earth, adduced in support of this theory, does not of necessity imply an universal and simultaneous fluidity in the beginning; for supposing the original figure of our planet had been strictly spherical—which, however, is a gratuitous assumption, resting on no established analogy — still the statical figure must have been assumed, if sufficient time be allowed, by the gradual operation of the centrifugal force, acting on the materials brought successively within its action by aqueous and igneous causes.

4thly. It appears, from experiment, that the heat in mines increases progressively with their depth; and if the ratio of increase be continued uniformly from the surface to the interior, the whole globe, with the

exception of a small external shell, must be fluid, and the central parts must have a temperature many times higher than that of melted iron.

5thly. But the theory adopted by M. Cordier and others, which maintains the actual existence of such a state of things, seems wholly inconsistent with the laws which regulate the circulation of heat through fluid bodies. For, if the central heat were as intense as is represented, there must be a circulation of currents, tending to equalize the temperature of the resulting fluid, and the solid crust itself would be melted.

6thly. Instead of an original central heat, we may, perhaps, refer the heat of the interior to chemical changes constantly going on in the earth's crust; for the general effect of chemical combination is the evolution of heat and electricity, which, in their turn, become sources of new chemical changes.

7thly. The existence of currents of electricity in the shell of the earth has been deduced from the phenomena of terrestrial magnetism; from the connection between the diurnal variations of the magnet and the apparent motion of the sun; from observations on the electro-magnetic properties of metalliferous veins; and, lastly, from atmospheric electricity, which is continually passing between the air and the earth.

8thly. Subterranean electric currents may exert a slow decomposing power like that of the voltaic pile, and thus become a constant source of chemical action, and, consequently, of volcanic heat.

9thly. It has been suggested, that the metals of the earths and alkalies may exist in an unoxidized state in the subterranean regions, and that the occasional con-

tact of water with these metals must produce intense heat. The hydrogen, evolved during the process of saturation, may, on coming afterwards in contact with the heated metallic oxides, reduce them again to metals; and this circle of action may be one of the principal means by which internal heat, and the stability of the volcanic energy, are preserved.

CHAPTER XIX.

CAUSES OF EARTHQUAKES AND VOLCANOS—*continued.*

Heat of the interior of the earth — Causes of earthquakes — Expansive power of condensed gases — How land may be permanently elevated—Expansion of rocks by heat (p. 383.)—Subsidence of land — Volcanic eruptions — Geysers of Iceland— Whether decomposition of water a source of volcanic heat — Almost all volcanos near the sea (p. 391.)—Many subterranean changes now unseen; therefore many geological phenomena obscure — Average annual number of earthquakes — Elevatory movements alone not opposed to the levelling force of running water — The sinking in of the earth's crust must exceed the forcing out of the same by earthquakes (p. 398.)— Whether earthquakes have diminished in energy — Conservative influence of volcanic action.

When we reflect that the largest mountains are but insignificant protuberances upon the surface of the earth, and that these mountains are nevertheless composed of different parts which have been formed in succession, we may well feel surprise that the central fluidity of the planet should have been called in to account for volcanic phenomena. To suppose the entire globe to be in a state of igneous fusion, with the exception of a solid shell, not more than from thirty to one hundred miles thick, and to imagine that the central heat of this fluid spheroid exceeds by more than two hundred times that of liquid lava, is to introduce a force altogether disproportionate to the effects which it is required to explain.

The ordinary repose of the surface implies, on the contrary, an inertness in the internal mass which is truly wonderful. When we consider the combustible nature of the elements of the earth, so far as they are known to us, — the facility with which their compounds may be decomposed, and made to enter into new combinations, — the quantity of heat which they evolve during these processes; when we recollect the expansive power of steam, and that water itself is composed of two gases which, by their union produce intense heat; when we call to mind the number of explosive and detonating compounds which have been already discovered, we may be allowed to share the astonishment of Pliny, that a single day should pass without a general conflagration:—" Excedit profectò omnia miracula, ullum diem fuisse quo non cuncta conflagrarent."*

The signs of internal heat observable on the surface of the earth do not necessarily indicate the permanent existence of subterranean heated masses, whether fluid or solid, by any means so vast as our continents and seas; yet how insignificant would these appear if distributed through an external shell of the globe one or two hundred miles in depth! The principal facts in proof of the accumulation of heat below the surface may be summed up in a few words. Several volcanos are constantly in eruption, as Stromboli and Nicaragua; others are known to have been active for periods of 60, or even 150 years, as those of Sangay in Quito, Popocatepetl in Mexico, and the volcano of the Isle of Bourbon. Many craters emit hot vapours in the intervals between eruptions, and solfataras evolve inces-

* Hist. Mundi, lib. ii. c. 107.

Fig. 46.

Centre of the Earth.

santly the same gases as volcanos. Steam of high temperature has continued for more than twenty centuries to issue from the "stufas," as the Italians call them,—thermal springs abound not only in regions of earthquakes, but are found in almost all countries, however distant from active vents; and, lastly, the temperature in the mines of various parts of the world is found to increase in proportion as we descend.

It is probably to this unceasing discharge of subterranean heat that we owe the general tranquillity of the globe; and the occasional convulsions which occur may arise from the temporary stoppage of the channels by which heat is transmitted to the surface; for the passage of caloric from below upwards may be compared to the descent of water from the continents to the sea; and as a partial interruption of the drainage of a country causes a flood, so any obstruction to the discharge of volcanic heat may give rise to an earthquake or eruption.

The annexed diagram* may convey some idea of the proportion which our continents and the ocean bear to the radius of the earth. If all the land were about as high as the Himalaya mountains, and the ocean every where as deep as the Pacific, the whole of both might be contained within a space expressed by the thickness of the line *a b*; and masses of nearly equal volume might be placed in the space marked by the line *c d*, in the interior. Seas of lava, therefore, of the size of the Mediterranean, or even of the Atlantic, would be as nothing if distributed through such an outer shell of the globe as is represented by

* Reduced, by permission, from a figure in plate 40. of Mr. De la Beche's Geological Sections and Views.

the shaded portion of the figure *a b c d*. If throughout that space we imagine electro-chemical causes to be continually in operation, even of very feeble power, they might give rise to heat which, if accumulated at certain points, might melt or render red-hot entire mountains, or sustain the temperature of stufas and hot springs for ages.

Causes of earthquakes — wave-like motion. — I shall now proceed to examine the manner in which the heat of the interior may give rise to earthquakes; and shall then pass on to the probable causes of eruptions. One of the most common phenomena attending subterranean movements, is the undulatory motion of the ground. And this, says Michell, will seem less extraordinary, if we call to mind the extreme elasticity of the earth, and the compressibility of even the most solid materials. Large districts, he suggests, may rest on fluid lava; and, when this is disturbed, its motions may be propagated through the incumbent rocks. He also adds the following ingenious speculation:—"As a small quantity of vapour almost instantly generated at some considerable depth below the surface of the earth will produce a vibratory motion, so a very large quantity (whether it be generated almost instantly, or in any small portion of time) will produce a wave-like motion. The manner in which this wave-like motion will be propagated may, in some measure, be represented by the following experiment: —Suppose a large cloth, or carpet (spread upon a floor), to be raised at one edge, and then suddenly brought down again to the floor; the air under it, being by this means propelled, will pass along, till it escapes at the opposite side, raising the cloth in a wave all the way as it goes. In like manner, a large quantity of

vapour may be conceived to raise the earth in a wave, as it passes along between the strata, which it may easily separate in a horizontal direction, there being little or no cohesion between one stratum and another. The part of the earth that is first raised, being bent from its natural form, will endeavour to restore itself by its elasticity; and the parts next to it being to have their weight supported by the vapour, which will insinuate itself under them, will be raised in their turn, till it either finds some vent, or is again condensed by the cold into water, and by that means prevented from proceeding any farther."*

To this hypothesis of Michell it has been objected, with some reason, that the wave-like movements of the surface of the land during earthquakes, though violent, are on a very minute scale; as appears from the account of tall trees touching the ground with their tops, and then resuming their erect position, the sea-sickness experienced by spectators, and other phenomena, clearly indicating that the radius of each superficial curvature is very small. On the other hand, the sudden fracture, it is said, of solid strata, might produce a vibratory jar; which, being propagated in undulations through a mass of rock several thousand feet thick, would give rise to superficial waves, even though the subjacent crust of the globe were entirely solid, and not reposing either on fluid or gaseous matter.†

The facility with which all the particles of a solid mass can be made to vibrate, may be illustrated, says

* On the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. sect. 58. 1760.

† Quarterly Review, No. lxxxvi. p. 463.

Gay-Lussac, by many familiar examples. If we apply the ear to one end of a long wooden beam, and listen attentively when the other end is struck by a pin's head, we hear the shock distinctly; which shows that every fibre throughout the whole length has been made to vibrate. The rattling of carriages on the pavement shakes the largest edifices; and in the quarries underneath some quarters in Paris, it is found that the movement is communicated through a considerable thickness of rock.*

The rending and upheaving of continental masses are operations which are not difficult to explain, when we are once convinced that heat, of sufficient power not only to melt, but to reduce to a gaseous form a great variety of substances, is accumulated in certain parts of the interior. We see that elastic fluids are capable of projecting solid masses to immense heights in the air; and the volcano of Cotopaxi has been known to throw out, to the distance of eight or nine miles, a mass of rock about one hundred cubic yards in volume. When we observe these aëriform fluids rushing out from particular vents for months, or even years, continuously, what power may we not expect them to exert in other places, where they happen to be confined under an enormous weight of rock?

Liquid gases. — The experiments of Faraday and others have shown, within the last twelve years, that many of the gases, including all those which are most copiously disengaged from volcanic vents, as the carbonic, sulphurous, and muriatic acids, may be condensed into liquids by pressure. At temperatures of from 30° to 50° F., the pressure required for this purpose varies from fifteen to fifty atmospheres; and this

* Ann. de Ch. et de Ph., tom. xxii. p. 428.

amount of pressure we may regard as very insignificant in the operations of nature. A column of Vesuvian lava that would reach from the lip of the crater to the level of the sea, must be equal to about three hundred atmospheres; so that, at depths which may be termed moderate in the interior of the crust of the earth, the gases may be condensed into liquids, even at very high temperatures. The method employed to reduce some of these gases to a liquid state is, to confine the materials, from the mutual action of which they are evolved, in tubes hermetically sealed, so that the accumulated pressure of the vapour, as it rises and expands, may force some part of it to assume the liquid state. A similar process may, and indeed must, frequently take place in subterranean caverns and fissures, or even in the pores and cells of many rocks; by which means, a much greater store of expansive power may be *packed* into a small space than could happen if these vapours had not the property of becoming liquid. For, although the gas occupies much less room in a liquid state, yet it exerts exactly the same pressure upon the sides of the containing cavity as if it remained in the form of vapour.

If a tube, whether of glass or other materials, filled with condensed gas, have its temperature slightly raised, it will often burst; for a slight increment of heat causes the elasticity of the gas to increase in a very high ratio. We have only to suppose certain rocks permeated by these liquid gases (as porous strata are sometimes filled with water), to have their temperature raised some hundred degrees; and we obtain a power capable of lifting superincumbent masses of almost any conceivable thickness; while, if the depth at which the gas is confined be great,

there is no reason to suppose that any other appearances would be witnessed by the inhabitants of the surface than vibratory movements and rents, from which no vapour might escape. In making their way through fissures a very few miles only in length, or in forcing a passage through soft yielding strata, the vapours may be cooled and absorbed by water. For water has a strong affinity to several of the gases; and will absorb large quantities, with a very slight increase of volume. In this manner, the heat or the volume of springs may be augmented, and their mineral properties made to vary.

Permanent elevation and subsidence. — It is easy to conceive that the shattered rocks may assume an arched form during a convulsion, so that the country above may remain permanently upheaved. In other cases, gas may drive before it masses of liquid lava, which may thus be injected into newly opened fissures. The gas having then obtained more room, by the forcing up of the incumbent rocks, may remain at rest; while the lava, congealing in the rents, may afford a solid foundation for the newly raised district.

Experiments have recently been made in America, by Colonel Totten, to ascertain the ratio according to which some of the stones commonly used in architecture expand with given increments of heat.* It was found impossible, in a country where the annual variation of temperature was more than 90° F., to make a coping of stones, five feet in length, in which the joints should fit so tightly as not to admit water between the stone and the cement; the annual contraction and

* Silliman's American Journ., vol. xxii. p. 136. The application of these results to the theory of earthquakes, was first suggested to me by Mr. Babbage.

expansion of the stones causing, at the junctions, small crevices, the width of which varied with the nature of the rock. It was ascertained that fine-grained granite expanded with 1° F. at the rate of ·000004825; white crystalline marble ·000005668; and red sandstone ·000009532, or about twice as much as granite.

Now, according to this law of expansion, a mass of sandstone, a mile in thickness, which should have its temperature raised 200° F., would lift a superimposed layer of rock to the height of ten feet above its former level. But, suppose a part of the earth's crust, one hundred miles in thickness and equally expansible, to have its temperature raised 600° or 800°, this might produce an elevation of between two and three thousand feet. The cooling of the same mass might afterwards cause the overlying rocks to sink down again and resume their original position. By such agency we might explain the gradual rise of Scandinavia or the subsidence of Greenland, if this last phenomenon should also be established as a fact on further inquiry.

It is also possible that as the clay in Wedgwood's pyrometer contracts, by giving off its water, and then, by incipient vitrification; so, large masses of argillaceous strata in the earth's interior may shrink, when subjected to heat and chemical changes, and allow the incumbent rocks to subside gradually. It may frequently happen that fissures of great extent may be formed in rocks simply by the unequal expansion of a continuous mass, heated in one part, while in another it remains at a comparatively low temperature. The sudden subsidence of land may also be occasioned by subterranean caverns giving way, when gases are condensed, or when they escape through newly-formed

crevices. The subtraction, moreover, of matter from certain parts of the interior, by the flowing of lava, and of mineral springs, must, in the course of ages, cause vacuities below, so that the undermined surface may at length fall in.

Cause of volcanic eruptions. — The most probable causes of a volcanic outburst at the surface have been in a great degree anticipated in the preceding speculations on the liquefaction of rocks and the generation of gases. When a minute hole is bored in a tube filled with gas condensed into a liquid, the whole becomes instantly aëriform, or, as some writers have expressed it, "flashes into vapour," and often bursts the tube. Such an experiment may represent the mode in which gaseous matter may rush through a rent in the rocks, and continue to escape for days or weeks through a small orifice, with an explosive power sufficient to reduce every substance which opposes its passage into small fragments, or even dust. Lava may be propelled upwards at the same time, and ejected in the form of scoriæ. In some places, where the fluid lava lies in a space intervening between a fissure, communicating with the surface, and a cavern in which a considerable body of vapour has been formed, there will be an efflux of lava, followed by the escape of gas. Eruptions often commence and close with the discharge of vapour; and, when this is the case, the next outburst may be expected to take place by the same vent, for the concluding evolution of elastic fluids will open the duct, and leave it unobstructed.

The breaking out of lava from the side or base of a lofty cone, rather than from the summit, may be attributed to the hydrostatic pressure to which the flanks of the mountain are exposed, when the column

of lava has risen to a great height. If, before it has reached the top, there should happen to be a stoppage of the main duct, the upward pressure of the ascending column of gas and lava may be sufficient to burst a lateral opening.

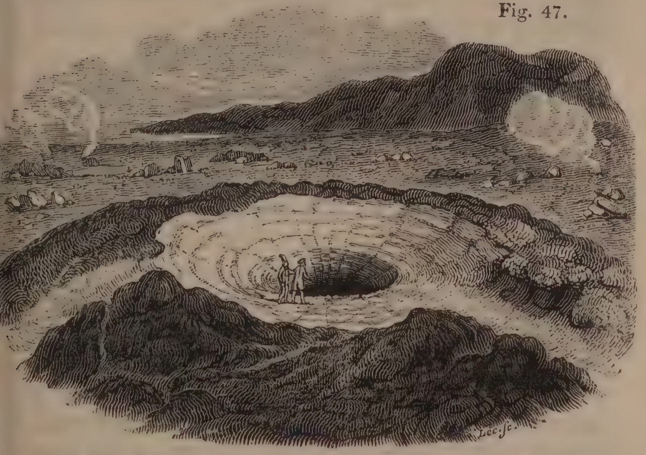
Geysers of Iceland.—As aqueous vapour constitutes the most abundant of the aëriform products of volcanos in eruption, it may be well to consider attentively a case in which steam is exclusively the moving power—that of the Geysers of Iceland. These intermittent hot springs occur in a district situated in the south-western division of Iceland, where nearly one hundred of them are said to break out within a circle of two miles. They rise through a thick current of lava, which may perhaps have flowed from Mount Hecla, the summit of that volcano being seen from the spot at the distance of more than thirty miles. In this district, the rushing of water is sometimes heard in chasms beneath the surface; for here, as on Etna, rivers flow in subterranean channels through the porous and cavernous lavas. It has more than once happened, after earthquakes, that some of the boiling fountains have increased or diminished in violence and volume, or entirely ceased, or that new ones have made their appearance—changes which may be explained by the opening of new rents and the closing of pre-existing fissures. It has often been reported that the powers of the Geysers are, upon the whole, on the decline; but the description given by Mr. Barrow, Jun. of the eruptions in 1834, agrees very closely with that of Sir J. Banks, written more than 60 years before.*

Few of the Geysers play longer than five or six

* See Barrow's visit to Iceland, ch. vi. 1834.

minutes at a time, and the intervals between their eruptions are for the most part very irregular. The great Geyser rises out of a spacious basin at the summit of a circular mound composed of siliceous incrustations deposited from the spray of its waters. The diameter of this basin, in one direction, is fifty-six feet, and forty-six in another.

Fig. 47.



View of the Crater of the great Geyser in Iceland.

In the centre is a pipe seventy-eight feet in perpendicular depth, and from eight to ten feet in diameter, but gradually widening, as it rises into the basin. The inside of the basin is whitish, consisting of a siliceous crust, and perfectly smooth, as are likewise two small channels on the sides of the mound, down which the water escapes when the bowl is filled to the margin. The circular basin is sometimes empty, as represented

* Reduced from a sketch given by W. J. Hooker, M.D., in his Tour in Iceland, vol. i. p. 149.

in the above sketch; but is usually filled with beautifully transparent water in a state of ebullition. During the rise of the boiling water in the pipe, especially when the ebullition is most violent, and when the water is thrown up in jets, subterranean noises are heard, like the distant firing of cannon, and the earth is slightly shaken. The sound then increases and the motion becomes more violent, till at length a column of water is thrown up, with loud explosions, to the height of one or two hundred feet. After playing for a time like an artificial fountain, and giving off great clouds of vapour, the pipe or tube is emptied; and a column of steam rushing up with amazing force and a thundering noise, terminates the eruption.

If stones are thrown into the crater, they are instantly ejected; and such is the explosive force, that very hard rocks are sometimes shivered by it into small pieces. Henderson found that by throwing a great quantity of large stones into the pipe of Strockr, one of the Geysers, he could bring on an eruption in a few minutes.* The fragments of stone, as well as the boiling water, were thrown in that case to a much greater height than usual. After the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour; but the Geyser, as if exhausted by this effort, did not send out a fresh eruption when its usual interval of rest had elapsed.

Among the different theories proposed to account for these phenomena, I shall first mention one suggested by Sir J. Herschel. An imitation of these jets, he says, may be produced on a small scale, by heating red hot the stem of a tobacco pipe, filling the bowl with water, and so inclining the pipe as to let the

* Journal of a Residence in Iceland, p. 74.

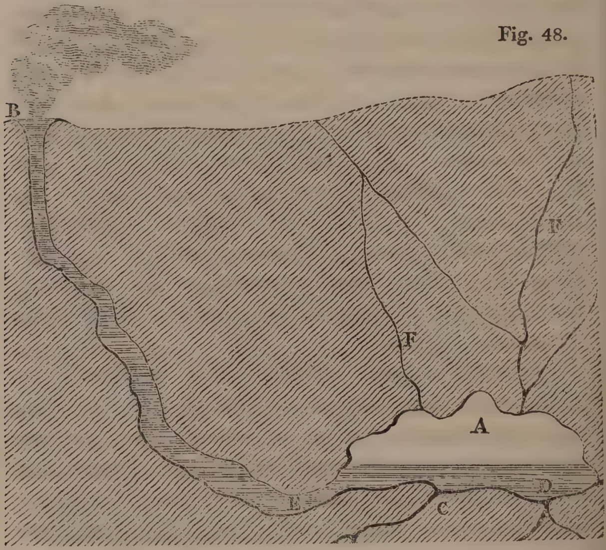
water run through the stem. Its escape, instead of taking place in a continued stream, is then performed by a succession of violent explosions, at first of steam alone, then of water mixed with steam; and, as the pipe cools, almost wholly of water. At every such paroxysmal escape of the water a portion is driven back, accompanied with steam, into the bowl. The intervals between the explosions depend on the heat, length, and inclination of the pipe; their continuance, on its thickness and conducting power.* The application of this experiment to the Geysers merely requires that a subterranean stream, flowing through the pores and crevices of lava, should suddenly reach a fissure, in which the rock is red hot, or nearly so. Steam would immediately be formed, which, rushing up the fissure, might force up water along with it to the surface, while, at the same time, part of the steam might drive back the water of the supply for a certain distance towards its source. And when, after the space of some minutes, the steam was all condensed, the water would return, and a repetition of the phenomena take place.

There is, however, another mode of explaining the action of the Geyser perhaps more probable than that above described. Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D by the fissures F F, while, at the same time, steam, at an extremely high temperature, such as is commonly given out from the rents of lava currents during congelation, emanates from the fissures C. A portion of the steam is at first condensed into water, while the temperature of the water is raised

* MS. read to Geol. Soc. of London, Feb. 29. 1832.

by the latent heat thus evolved, till, at last, the lower part of the cavity is filled with boiling water and the upper with steam under high pressure. The expansive force of the steam becomes, at length, so great, that the water is forced up the fissure or pipe E B, and runs over the rim of the basin. When the pressure is thus diminished, the steam in the upper part of the cavity A expands, until all the water D is driven into the pipe: and when this happens, the steam, being the lighter of the two fluids, rushes up through the

Fig. 48.



*Supposed reservoir and pipe of a Geyser in Iceland.**

water with great velocity. If the pipe be choked up artificially, even for a few minutes, a great increase of heat must take place; for it is prevented from escaping

* From Sir George Mackenzie's Iceland.

in a latent form in steam; so that the water is made to boil more violently, and this brings on an eruption.

If we suppose that large subterranean cavities exist at the depth of some miles below the surface of the earth, in which melted lava accumulates, and that water penetrates into these, the steam thus generated may press upon lava and force it up the duct of a volcano, in the same manner as a column of water is driven up the pipe of a Geyser.

Agency of water in volcanos. — No theory seems at first more improbable, than that which represents water as affording an inexhaustible supply of fuel to the volcanic fires; yet, if subterraneous heat be derived from chemical action, as before hinted, and if electric currents in the crust of the earth may exert a slow decomposing power, the hypothesis is far from visionary.

It is a fact that must never be overlooked, when we are speculating on the probable causes of volcanos, that, while a great number are entirely submarine, the remainder are for the most part in islands or maritime tracts. There are a few exceptions, but some of these, as Dr. Daubeny observes, are near inland salt lakes, as in Central Tartary; while others form part of a train of volcanos the extremities of which are near the sea. Thus Jorullo, in Mexico, though itself not less than forty leagues from the nearest ocean, appears to be connected with the volcano of Tuxtla on the one hand, and that of Colima on the other; the first bordering on the Atlantic, the latter on the Pacific Ocean. This communication is rendered more probable by the parallelism that exists between these and several intermediate volcanic hills.*

* See Daubeny's remarks — "Volcanos," p. 368.

Sir H. Davy supposes that, when the sea is distant, as in the case of some of the South American volcanos, they may still be supplied with water from subterranean lakes; since, according to Humboldt, large quantities of fish are often thrown out during eruptions.*

It has been already stated, that the gases exhaled from volcanos, together with steam, are such as would result from the decomposition of salt water, and the fumes which escape from the Vesuvian lava have been observed to deposit common salt.† The emission of free muriatic acid gas in great quantities favours the theory of the decomposition of the salt contained in sea water; but M. Boussingault did not meet with this gas in his late examination of the elastic fluids evolved from the volcanos of equatorial America. He informs us, that the same are given out by all the different vents, namely, aqueous vapour, in very large quantity, carbonic acid gas, sulphurous acid gas, and sometimes fumes of sulphur. The same naturalist found by analysis, that all the thermal waters of the Cordilleras were charged with sulphuretted hydrogen gas.‡

M. Gay Lussac, while he avows his opinion that the decomposition of water contributes largely to volcanic action, calls attention, nevertheless, to the fact, that hydrogen has not been detected in a separate form among the gaseous products of volcanos; nor can it, he says, be present; for, in that case, it would be inflamed in the air by the red-hot stones thrown out during an eruption. Dr. Davy, also, in his account

* Phil. Trans., 1828, p. 250.

† Davy, Phil. Trans., 1828, p. 244.

‡ Ann. de Chim. et de Phys., tom. lii. p. 181.

of Graham island, says, "I watched when the lightning was most vivid, and the eruption of the greatest degree of violence, to see if there was any inflammation occasioned by this natural electric spark — any indication of the presence of inflammable gas; but in vain."*

May not the hydrogen, Gay Lussac inquires, be combined with chlorine, and produce muriatic acid? for this gas has been observed to be evolved from Vesuvius — and the chlorine may have been derived from sea salt; which was, in fact, extracted by simple washing from the Vesuvian lava of 1822, in the proportion of nine per cent.† But it was answered, that Sir H. Davy's experiments had shown, that hydrogen is not combustible when mixed with muriatic acid gas; so that if muriatic gas was evolved in large quantities, the hydrogen might be present without inflammation.‡

M. Gay Lussac, in the memoir just alluded to, expresses doubt as to the presence of sulphurous acid; but the abundant disengagement of this gas during eruptions is now ascertained: and thus all difficulty in regard to the absence of hydrogen in an inflammable state is removed. For, as Dr. Daubeny supposes, the hydrogen of decomposed water may unite with sulphur to form sulphuretted hydrogen gas, and this gas will then be mingled with the sulphurous acid as it rises to the crater. It is shown by experiment, that these gases mutually decompose each other when mixed where steam is present; part of the hydrogen of the one immediately uniting with the oxygen of the other,

* Phil. Trans., 1832, p. 240.

† Ann. de Chim. et de Phys., tom. xxii.

‡ Quart. Journ. of Science, 1823, p. 132. note by editor.

to form water, while the excess of sulphurous acid alone escapes into the atmosphere. Sulphur is at the same precipitated.

This explanation is sufficient, but it may be asked, whether the flame of hydrogen would be visible during an eruption; as that gas, when inflamed in a pure state, burns with a very faint blue flame, which even in the night could hardly be perceptible by the side of red-hot and incandescent cinders. Its immediate conversion into water when inflamed in the atmosphere, might also account for its not appearing in a separate form.

When treating of springs and overflowing wells, I have stated that porous rocks are percolated by fresh water to great depths, and that sea-water probably penetrates in the same manner through the rocks which form the bed of the ocean. But, besides this universal circulation in regions not far from the surface, it must be supposed that, wherever earthquakes prevail, much larger bodies of water will be forced by the pressure of the ocean into fissures at greater depths, or swallowed up in chasms; in the same manner as, on the land, towns, houses, cattle, and trees are sometimes engulphed. It will be remembered, that these chasms often close again after houses have fallen into them; and, for the same reason, when water has penetrated to a mass of melted lava, the steam into which it is converted may often rush out at a different aperture from that by which the water entered. The frequent explosions caused by the generation of steam in the neighbourhood of the sea or of deep lakes, may shatter the solid crust of the earth, and allow the free escape of gases and lava which, but for this cause, might never have reached the surface, and might only have given rise to earthquakes.

Dr. Daubeny has suggested that water containing atmospheric air may descend from the surface of the earth to the volcanic foci, and that the same process of combustion by which water is decomposed may deprive such subterranean air of its oxygen. In this manner we might explain the great quantities of nitrogen evolved from volcanic vents, and thermal waters, and the fact that air disengaged from the earth in volcanic regions is either wholly or in part deprived of its oxygen.

Sir H. Davy, in his memoir on the "Phenomena of Volcanos," remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air; and he imagined that subterranean cavities which threw out large volumes of steam during the eruption, might afterwards, in the quiet state of the volcano, become filled with atmospheric air.* The presence of ammoniacal salts in volcanic emanations, and of ammonia in lava, favours greatly, says Dr. Daubeny, the notion of air as well as water being deoxidated in the interior of the earth.†

Such phenomena admit of a ready explanation on the principles of the chemical theory of volcanos, considered in the last chapter; but are left unexplained by the hypothesis of the gradual contraction of an external crust upon a fluid nucleus.

Importance of attending to the unseen volcanic phenomena. — In concluding these remarks on the causes of volcanos and earthquakes, I may observe, that speculations and conjectures on this obscure subject

* Phil. Trans. 1828.

† Ammonia is composed of hydrogen and nitrogen: or the elements of air without its oxygen. See Daubeny, Encyc. Metrop., Part 40.

should be encouraged; because a great step is gained, if geologists are rendered more conscious of the changes in the earth's crust now going on *out of sight*, and under circumstances widely different from any which can ever come within the sphere of human observation. In estimating the effects of existing causes, we are too apt to confine our views to operations such as we actually see in progress upon the habitable surface, regardless of those which must be going on at various depths below. But when we examine the geological structure of the earth, we behold the results of former processes both subterranean and superficial; and recognize at once the exact agreement of many of the superficial class with the effects of known causes. To what agency, then, ought we to refer the phenomena which still remain unexplained? Surely not to imaginary forces, which may by possibility have prevailed in the infancy of the planet; but rather to the unseen portion of that machinery which is still at work. Let it be supposed that a person has made such progress in a foreign language — German, for example — that, in perusing the works of living authors, he understands the meaning of about two thirds of what he reads. If, on taking up a book written two or three centuries ago, he finds that he is able to interpret about as much of that also, he might naturally conclude that the language had remained the same, or nearly the same, during the intervening time. Would he have any doubt respecting this identity, from being unable to comprehend *all* that is written in the older volume? or would he not, on the contrary, think it unreasonable, while he remains ignorant of a great part of the living language, to expect to interpret every thing in the ancient book?

The balance of dry land, how preserved.—In the present state of our knowledge, we cannot pretend to estimate the average number of earthquakes which may happen in the course of a single year. As the area of the ocean is nearly three times that of the land, it is probable that about three submarine earthquakes may occur for one exclusively continental: and when we consider the great frequency of slight movements in certain districts, we can hardly suppose that a day ever passes without one or more shocks being experienced in some part of the globe. We have also seen that in Sweden, and other countries, changes in the relative level of sea and land may take place without commotion, and these perhaps produce the most important geographical and geological changes; for the position of land may be altered to a greater amount by an elevation or depression of one inch over a vast area, than by the sinking of a more limited tract, such as the forest of Aripao, to the depth of many fathoms at once.*

It must be evident, from the historical details above given, that the force of subterranean movement, whether intermittent or continuous, whether with or without disturbance, does not operate at random, but is developed in certain regions only; and although the alterations produced during the time required for the occurrence of a few volcanic eruptions may be inconsiderable, we can hardly doubt that, during the ages necessary for the formation of large volcanic cones, composed of thousands of lava currents, shoals might be converted into lofty mountains, and low lands into deep seas.

* See p. 251.

In a former chapter, I have stated that aqueous and igneous agents may be regarded as antagonist forces; the aqueous labouring incessantly to reduce the inequalities of the earth's surface to a level, while the igneous are equally active in renewing the unevenness of the surface.* By some geologists it has been thought that the levelling power of running water was opposed rather to the *elevating* force of earthquakes than to their action generally. This opinion is, however, untenable; for the sinking down of the bed of the ocean is one of the means by which the gradual submersion of land is prevented. The depth of the sea cannot be increased at any one point without a universal fall of the waters, nor can any partial deposition of sediment occur without the displacement of a quantity of water of equal volume, which will raise the sea, though in an imperceptible degree, even to the antipodes. The preservation, therefore, of the dry land may sometimes be effected by the subsidence of part of the earth's crust (that part, namely, which is covered by the ocean), and in like manner an upheaving movement must often tend to destroy land; for if it render the bed of the sea more shallow, it will displace a certain quantity of water, and thus tend to submerge low tracts.

Astronomers having proved that there has been no change in the diameter of the earth during the last two thousand years, we may assume it as probable, that the dimensions of the planet remain uniform.† If, then, we inquire in what manner the force of earthquakes must be regulated, in order to restore perpetually the inequalities of the surface which the levelling power of water tends to efface, it will be found,

* Book ii. chap. i. † Vol. i. p. 217.

that the amount of depression must exceed that of elevation. It would be otherwise if the action of volcanos and mineral springs were suspended; for then the forcing outwards of the earth's envelope ought to be no more than equal to its sinking in.

To understand this proposition more clearly, it must be borne in mind, that the deposits of rivers and currents probably add as much to the height of lands which are rising, as they take from those which have risen. Suppose a large river to bring down sediment to a part of the ocean two thousand feet deep, and that the depth of this part is gradually reduced by the accumulation of sediment till only a shoal remains, covered by water at high tides; if now an upheaving force should uplift this shoal to the height of 2000 feet, the result would be a mountain 2000 feet high. But had the movement raised the same part of the bottom of the sea before the sediment of the river had filled it up; then, instead of changing a shoal into a mountain 2000 feet high, it would only have converted a deep sea into a shoal.

It appears, then, that the operations of the earthquake are often such as to cause the levelling power of water to counteract itself; and, although the idea may appear paradoxical, we may be sure, wherever we find hills and mountains composed of stratified deposits, that such inequalities of the surface would have had no existence if water, at some former period, had not been labouring to reduce the earth's surface to one level.

But, besides the transfer of matter by running water from the continents to the ocean, there is a constant transportation from below upwards, by mineral springs and volcanic vents. As mountain masses are, in the

course of ages, created by the pouring forth of successive streams of lava, so stratified rocks, of great extent, originate from the deposition of carbonate of lime, and other mineral ingredients, with which springs are impregnated. The surface of the land, and portions of the bottom of the sea, being thus raised, the external accessions due to these operations would cause the dimensions of the planet to enlarge continually, if the amount of depression of the earth's crust were no more than equal to the elevation. In order, therefore, that the mean diameter of the earth should remain uniform, and the unevenness of the surface be preserved, it is necessary that the amount of subsidence should be in excess. And such a predominance of depression is far from improbable, on mechanical principles, since every upheaving movement must be expected either to produce caverns in the mass below, or to cause some diminution of its density. Vacuities must, also, arise from the subtraction of the matter poured out from volcanos and mineral springs; and the foundations having been thus weakened, the earth's crust, shaken and rent by reiterated convulsions, must, in the course of time, fall in.

If we embrace these views, important geological consequences will follow; since, if there be, upon the whole, more subsidence than elevation, the average depth to which former surfaces have sunk beneath their original level must exceed the height which ancient marine strata have attained above the sea. If, for example, marine strata, about the age of our chalk and green-sand, have been lifted up in Europe to an extreme height of more than eleven thousand feet, and a mean elevation of some hundreds, we may conclude that certain parts of the surface, which existed when

those strata were deposited, have sunk to an extreme depth of *more than* eleven thousand feet below their original level, and to a mean depth of *more than* a few hundreds.

In regard to faults, also, we must infer, according to the hypothesis now proposed, that a greater number have arisen from the sinking down than from the elevation of rocks.

Mr. Conybeare, and some other writers, have contended, that the upheaving force of earthquakes was more energetic during remote geological epochs, and that it has since been gradually on the decline*; while M. Elie de Beaumont, on the contrary, maintains, that the most tremendous of known convulsions belong to times comparatively modern.† But in order to compare the relative amount of change produced, at different periods, by any given cause, we must obtain some standard for the measurement of time at both the periods compared.

I have shown that, during the last two thousand years, considerable tracts of land have been upheaved above, or depressed below their former level.‡ Now, they who contend that a greater or less amount of change was formerly accomplished in an equal number of years, must first explain the mode in which they measure the time referred to; for they cannot, in geology, avail themselves of the annual revolutions of our planet in its orbit. If they assume that the power of volcanos to emit lava, and of running water to transport sediment from one part of the globe to the other, has

* Phil. Mag., No. 48. Dec. 1830, p. 402.

† Ann. des Sci. Nat., 1829; — Phil. Mag., No. 58. Oct. 1831.

‡ See Chapters vi. vii. viii. and ix.

remained uniform from the earliest periods; they may then attempt to compare the effects of subterranean movements in ancient and modern times by reference to one common standard; and to show that, during the time required for the production of a certain number of lava currents, or of so many cubic yards of sediment, the elevation and depression of the earth's crust were once much greater than they are now. Or, if they premise that the progressive rate of change of species in the animal and vegetable kingdoms had been always uniform, they may then endeavour to prove the diminished energy of earthquakes, by showing that, in relation to the periods connected with the changes of organic species, earthquakes had become comparatively feeble.

But those who contend for the reduced activity of natural agents, have not attempted to support this line of argument; nor does our scanty acquaintance, both with the animate and inanimate world, warrant such generalizations. That it would be most premature, in the present state of natural history, to reason on the comparative rate of fluctuation in the species of organic beings in ancient and modern times, or at any two geological periods, will be more fully demonstrated, when I come, in the next book, to consider the intimate connexion between Geology and the study of the present condition of the animal and vegetable kingdoms.

To conclude: it seems to be rendered probable, by the views above explained, that the constant repair of the land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of

causes acting in the interior of the earth; which, although so often the source of death and terror to the inhabitants of the globe — visiting, in succession, every zone, and filling the earth with monuments of ruin and disorder — are, nevertheless, the agents of a conservative principle above all others essential to the stability of the system.

BOOK III.

CHAPTER I.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

Division of the subject — Examination of the question, Whether species have a real existence in nature? — Importance of this question in geology — Sketch of Lamarck's arguments in favour of the transmutation of species, and his conjectures respecting the origin of existing animals and plants (p. 407.) — His theory of the transformation of the orang outang into the human species.

The last book was occupied with the consideration of the changes brought about on the earth's surface, within the period of human observation, by inorganic agents; such, for example, as rivers, marine currents, volcanos, and earthquakes. But there is another class of phenomena relating to the organic world, which have an equal claim on our attention, if we desire to obtain possession of all the preparatory knowledge respecting the existing course of nature, which may be available in the interpretation of geological monuments. It appeared, from our preliminary sketch of the progress of the science, that the most lively interest was excited among its earlier cultivators, by the discovery of the remains of animals and plants in the interior of mountains frequently remote from the sea. Much controversy arose respecting the nature of these remains, the causes which may have brought them into so singular

a position, and the want of a specific agreement between them and known animals and plants. To qualify ourselves to form just views on these curious questions, we must first study the present condition of the animate creation on the globe.

This branch of our inquiry naturally divides itself into two parts: first, we may examine the vicissitudes to which species are subject; secondly, the processes by which certain individuals of these species occasionally become fossil. The first of these divisions will lead us, among other topics, to inquire, first, whether species have a real and permanent existence in nature? or whether they are capable, as some naturalists pretend, of being indefinitely modified in the course of a long series of generations? Secondly, whether, if species have a real existence, the individuals composing them have been derived originally from many similar stocks, or each from one only, the descendants of which have spread themselves gradually from a particular point over the habitable lands and waters? Thirdly, how far the duration of each species of animal and plant is limited by its dependence on certain fluctuating and temporary conditions in the state of the animate and inanimate world? Fourthly, whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place?

Whether species have a real existence in nature.— Before we can advance a step in our proposed inquiry, we must be able to define precisely the meaning which we attach to the term species. This is even more

necessary in geology than in the ordinary studies of the naturalist; for they who deny that such a thing as a species exists, concede nevertheless that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the geographer, in constructing his maps from century to century, may proceed as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration were brought about by the precession of the equinoxes; so, it is said, in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world; and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly, M. Geoffroy St. Hilaire has declared his opinion, that there has been an uninterrupted succession in the animal kingdom, effected by means of generation, from the earliest ages of the world up to the present day; and that the ancient animals whose remains have been preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. This notion is not very generally received, but we are

not warranted in assuming the contrary, without fully explaining the data and reasoning by which it may be refuted.

I shall begin by stating as concisely as possible all the facts and ingenious arguments by which the theory has been supported; and for this purpose I cannot do better than offer the reader a rapid sketch of Lamarck's statement of the proofs which he regards as confirmatory of the doctrine, and which he has derived partly from the works of his predecessors, and in part from original investigations.

His proofs and inferences will be best considered in the order in which they appear to have influenced his mind, and I shall then point out some of the results to which he was led while boldly following out his principles to their legitimate consequences.

Lamarck's arguments in favour of the transmutation of species.— The name of species, observes Lamarck, has been usually applied to "every collection of similar individuals produced by other individuals like themselves." * This definition, he admits, is correct; because every living individual bears a very close resemblance to those from which it springs. But this is not all which is usually implied by the term species; for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species.

In order to shake this opinion, Lamarck enters upon the following line of argument:—The more we ad-

* Phil. Zool. tom. i. p. 54.

vance in the knowledge of the different organized bodies which cover the surface of the globe, the more our embarrassment increases, to determine what ought to be regarded as a species, and still more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species; and sometimes we are induced to pronounce individuals but slightly differing, and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that every thing passes by insensible shades into something else: that even the more remarkable differences are evanescent, and that nature has, for the most part, left us nothing at our disposal for establishing distinctions, save trifling and, in some respects, puerile particularities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may presume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and even entire orders—nay, whole

classes, which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar; and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made himself master of the intermediate links, that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock; and these newly acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races.*

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate, and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organization, in such a manner that every thing in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate, a great difference of situation and exposure causes individuals to vary; but if these individuals continue to live and to be reproduced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a

word, at the end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species.*

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing, and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a particular species.† The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birth-place, and cultivated in gardens, undergo changes which render them no longer recognizable as the same plants. Many which were naturally hairy become smooth, or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperities; others, again, from the ligneous state which their stem possessed in hot climates, where they were indige-

* Phil. Zool., tom. i. p. 62. † Ibid.

nous, pass to the herbaceous; and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

"Is not the cultivated wheat" (*Triticum sativum*), asks Lamarck, "a vegetable brought by man into the state in which we now see it? Let any one tell me in what country a similar plant grows wild, unless where it has escaped from cultivated fields? Where do we find in nature our cabbages, lettuces, and other culinary vegetables, in the state in which they appear in our gardens? Is it not the same in regard to a great quantity of animals which domesticity has changed or considerably modified?"* Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild geese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances be also altered.

The numerous races of dogs which we have pro-

* Phil. Zool., tom. i. p. 227.

duced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great, that they would be readily admitted as specific between wild animals; "yet all these have sprung originally from a single race, at first approaching very near to a wolf, if, indeed, the wolf be not the true type which at some period or other was domesticated by man."

Although important changes in the nature of the places which they inhabit modify the organization of animals as well as vegetables; yet the former, says Lamarck, require more time to complete a considerable degree of transmutation; and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local particulars. These circumstances are as varied as are the characters of the species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same.*

Every considerable alteration in the local circum-

* Phil. Zool., tom. i. p. 232.

stances in which each race of animals exists causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater developement follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions.*

I must here interrupt the author's argument, by observing, that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse; or, on the contrary, be matured and augmented by active exertion; just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable — that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

It was necessary to point out to the reader this important chasm in the chain of evidence, because he might otherwise imagine that I had merely omitted the illustrations for the sake of brevity, but the plain truth is, that there were no examples to be found; and when Lamarck talks "of the efforts of internal senti-

* Phil. Zool., tom. i. p. 234.

ment," "the influence of subtle fluids," and "acts of organization," as causes whereby animals and plants may acquire *new organs*, he substitutes names for things; and, with a disregard to the strict rules of induction, resorts to fictions, as ideal as the "plastic virtue," and other phantoms, of the geologists of the middle ages.

It is evident that, if some well-authenticated facts could have been adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, time alone might then be supposed sufficient to bring about any amount of metamorphosis. The gratuitous assumption, therefore, of a point so vital to the theory of transmutation, was unpardonable on the part of its advocate.

But to proceed with the system: it being assumed as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete, and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however staggering and absurd it may seem, is logically deduced from the assumed premises. It is not the organs, or, in other words, the nature and form of the parts of the body of an animal, which have given rise to its habits, and its particular faculties; but, on the contrary, its habits, its manner of living, and those of its progenitors, have in the course of time determined the form of its body, the number and condition of its organs, in short, the faculties which it enjoys. Thus otters, beavers, waterfowl, turtles, and frogs, were not made web-footed in

order that they might swim; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base acquired a habit of extension, until, in the course of time, the broad membranes which now connect their extremities were formed.

In like manner, the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity; a habit which, in the course of many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The camelopard was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage; but, being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its fore legs became longer than the hinder, and its neck so elongated that it could raise its head to the height of twenty feet above the ground.

Another line of argument is then entered upon, in further corroboration of the instability of species. In order, it is said, that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another; but such sexual unions do take place, both among plants and animals; and although the offspring of such irregular connexions are usually sterile, yet

such is not always the case. Hybrids have sometimes proved prolific, where the disparity between the species was not too great; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species.*

But if the soundness of all these arguments and inferences be admitted, we are next to inquire, what were the original types of form, organization, and instinct, from which the diversities of character, as now exhibited by animals and plants, have been derived? We know that individuals which are mere varieties of the same species would, if their pedigree could be traced back far enough, terminate in a single stock; so, according to the train of reasoning before described, the species of a genus, and even the genera of a great family, must have had a common point of departure. What, then, was the single stem from which so many varieties of form have ramified? Were there many of these, or are we to refer the origin of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or, at least, with very few interruptions, from beings of more simple to those of a more compound structure; and, in proportion as the complexity of their organ-

* Phil. Zool., p. 64.

ization increases, the number and dignity of their faculties increase also. Among plants, a similar approximation to a graduated scale of being is apparent. Secondly, it appears, from geological observations, that plants and animals of more simple organization existed on the globe before the appearance of those of more compound structure, and the latter were successively formed at more modern periods: each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings; and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, so as to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his Telliamed, and by several modern writers; so that the tables were completely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker; and that there was a tendency to progressive deterioration in sublunary things when left to themselves —

——————— omnia fatis
In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of

philosophy imbued with this doctrine, that, to check this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed, and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life; until, in the course of ages, sensation was superadded to mere vitality: sight, hearing, and the other senses were afterwards acquired; then instinct and the mental faculties; until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive that when all the higher order of plants and animals were thus supposed to be comparatively modern, and have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances? Why are there such multitudes of infusoria and polyps, or of confervæ

and other cryptogamic plants? Why, moreover, has the process of development acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity; but a delegated power—a mere instrument—a piece of mechanism acting by necessity—an order of things constituted by the Supreme Being, and subject to laws which are the expressions of his will. This Nature is *obliged* to proceed gradually in all her operations; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds, and out of them elaborate the more compound, adding to them, successively, different systems of organs, and multiplying more and more their number and energy.

This Nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generation.* She is always beginning anew, day by day, the work of creation, by forming monads, or "rough draughts" (ébauches), which are the only living things she gives birth to *directly*.

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms.* These are gradually developed into the higher and more perfect classes by the slow but unceasing agency of two

* Animaux sans Vert. tom. i. p. 56. Introduction.

influential principles: first, *the tendency to progressive advancement* in organization, accompanied by greater dignity in instinct, intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For, as species spread themselves gradually over the globe, they are exposed from time to time to variations in climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development, by supplying them with nutriment, or destroying their foes. The nature, also, of each locality, is in itself fluctuating; so that, even if the relation of other animals and plants were invariable, the habits and organization of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But, in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan; and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the Orang-Outang into the human species.—Such is the machinery of the Lamarckian system; but the reader will hardly, perhaps, be able to form a perfect conception of so complicated a piece of mechanism, unless it is exhibited in motion, so that we may see in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. I have only space for exhibiting a small part of the entire process by which a complete metamorphosis is achieved, and shall, therefore, omit the mode by which, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape; passing on at once to the last grand step in the progressive scheme, by which the orang-outang, having been already evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances (concerning the exact nature of which tradition is unfortunately silent), the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged, for a long series of generations, to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals; and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed, insensibly, a conformation fitted to support them in an erect attitude, till at last these

animals could no longer go on all-fours without much inconvenience.

The Angola orang (*Simia troglodytes*, Linn.) is the most perfect of animals; much more so than the Indian orang (*Simia Satyrus*), which has been called the orang-outang, although *both* are *very inferior* to man in corporeal powers and intelligence. These animals frequently hold themselves upright; but their organization has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all-fours, showing clearly that this was the original position of the animal. Even in man, whose organization, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing, and can be supported only for a limited time, and by aid of the contraction of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the upright position be a state of repose: but, as the human head does not articulate in the centre of gravity, as the chest, belly, and other parts press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling. Children which have large heads and prominent bellies can hardly walk at the end even of two years; and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they

could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest them in organization and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods, and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded; while, in the mean time, the dominant race spread itself in every direction, and lived in large companies, where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect; and, in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external circumstances*, which causes such wide chasms in the regular series of animated being.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them

to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, although most of them were gregarious, acquired no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs—whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice; but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue, and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech.*

In effecting this mighty change, "the exigencies of the individuals were the sole agents; they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment." Hence, in this peculiar race, the origin of the admirable faculty of speech; hence also the diversity of languages, since

* Lamarck's Phil. Zool., tom.i. p. 356.

the distance of places where the individuals composing the race established themselves soon favoured the corruption of conventional signs.*

In conclusion, it may be proper to observe that the above sketch of the Lamarckian theory is no exaggerated picture, and those passages which have probably excited the greatest surprise in the mind of the reader are literal translations from the original.

* Lamarck's Phil. Zool., tom. i. p. 357.

CHAPTER II.

TRANSMUTATION OF SPECIES — *continued.*

Recapitulation of the arguments in favour of the theory of transmutation of species — Their insufficiency — Causes of difficulty in discriminating species — Some varieties possibly more distinct than certain individuals of distinct species (p. 432.) — Variability in a species consistent with a belief that the limits of deviation are fixed — No facts of transmutation authenticated — Varieties of the Dog — The Dog and Wolf distinct species — Mummies of various animals from Egypt identical in character with living individuals (p. 439.) — Seeds and plants from the Egyptian tombs — Modifications produced in plants by agriculture and gardening.

THE theory of the transmutation of species, considered in the last chapter, has met with some degree of favour from many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world by the regular action of secondary causes, we have seen that in truth many perplexing difficulties present themselves to one who attempts to establish the nature and reality of the specific character. And if once there appears ground of reasonable doubt, in regard to the

constancy of species, the amount of transformation which they are capable of undergoing may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.

Before entering upon the reasons which may be adduced for rejecting Lamarck's hypothesis, I shall recapitulate, in a few words, the phenomena, and the whole train of thought, by which I conceive it to have been suggested, and which have gained for this and analogous theories, both in ancient and modern times, a considerable number of votaries.

In the first place, the various groups into which plants and animals may be thrown seem almost invariably, to a beginner, to be so natural, that he is usually convinced at first, as was Linnæus to the last, "that genera are as much founded in nature as the species which compose them."* When, by examining the numerous intermediate gradations, the student finds all lines of demarcation to be in most instances obliterated, even where they at first appeared most distinct, he grows more and more sceptical as to the real existence of genera, and finally regards them as mere arbitrary and artificial signs, invented, like those which serve to distinguish the heavenly constellations, for the convenience of classification, and having as little pretensions to reality.

Doubts are then engendered in his mind as to whether species may not also be equally unreal. The student is probably first struck with the phenomenon, that some individuals are made to deviate widely from

* Genus omne est naturale, in primordio tale creatum, &c. Phil. Bot. § 159. See also ibid. § 162.

the ordinary type by the force of peculiar circumstances, and with the still more extraordinary fact, that the newly acquired peculiarities are faithfully transmitted to the offspring. How far, he asks, may such variations extend in the course of indefinite periods of time, and during great vicissitudes in the physical condition of the globe? His growing incertitude is at first checked by the reflection, that nature has forbidden the intermixture of the descendants of distinct original stocks, or has, at least, entailed sterility on their offspring, thereby preventing their being confounded together; and pointing out that a multitude of distinct types must have been created in the beginning, and must have remained pure and uncorrupted to this day.

Relying on this general law, he endeavours to solve each difficult problem by direct experiment, until he is again astounded by the phenomenon of a prolific hybrid, and still more by an example of a hybrid perpetuating itself throughout several generations in the vegetable world. He then feels himself reduced to the dilemma of choosing between two alternatives; either to reject the test, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If he prefer the latter, he is compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids: for although he may not be enabled immediately to procure, in all such instances, a fruitful offspring; yet experiments show, that after repeated failures, the union of two recognized species may at last, under very favourable circumstances, give birth to a fertile

progeny. Such circumstances, therefore, the naturalist may conceive to have occurred again and again, in the course of a great lapse of ages.

His first opinions are now fairly unsettled, and every stay at which he has caught has given way one after another; he is in danger of falling into any new and visionary doctrine which may be presented to him; for he now regards every part of the animate creation as void of stability, and in a state of continual flux. In this mood he encounters the Geologist, who relates to him how there have been endless vicissitudes in the shape and structure of organic beings in former ages—how the approach to the present system of things has been gradual—that there has been a progressive development of organization subservient to the purposes of life, from the most simple to the most complex state—that the appearance of man is the last phenomenon in a long succession of events; and finally, that a series of physical revolutions can be traced in the inorganic world, coeval and coextensive with those of organic nature.

These views seem immediately to confirm all his preconceived doubts as to the stability of the specific character, and he begins to think there may exist an inseparable connexion between a series of changes in the inanimate world, and the capability of the species to be indefinitely modified by the influence of external circumstances. Henceforth his speculations know no definite bounds; he gives the rein to conjecture, and fancies that the outward form, internal structure, instinctive faculties, nay, that reason itself may have been gradually developed from some of the simplest states of existence—that all animals, that man himself, and the irrational beings, may have had one common

origin; that all may be parts of one continuous and progressive scheme of development, from the most imperfect to the more complex; in fine, he renounces his belief in the high genealogy of his species, and looks forward, as if in compensation, to the future perfectibility of man in his physical, intellectual, and moral attributes.

Let us now proceed to consider what is defective in evidence, and what fallacious in reasoning, in the grounds of these strange conclusions. Blumenbach judiciously observes, that "no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*." The multitude, in fact, and complexity of the proofs to be weighed, is so great, that we can only hope to obtain presumptive evidence, and we must, therefore, be the more careful to derive our general views as much as possible from those observations where the chances of deception are least. We must be on our guard not to tread in the footsteps of the naturalists of the middle ages, who believed the doctrine of spontaneous generation to be applicable to all those parts of the animal and vegetable kingdoms which they least understood, in direct contradiction to the analogy of all the parts best known to them; and who, when at length they found that insects and cryptogamous plants were also propagated from eggs or seeds, still persisted in retaining their old prejudices respecting the infusory animalcules and other minute beings, the generation of which had not then been demonstrated by the microscope to be governed by the same laws.

Lamarck has, indeed, attempted to raise an argument

in favour of his system, out of the very confusion which has arisen in the study of some orders of animals and plants, in consequence of the slight shades of difference which separate the new species discovered within the last half century. That the embarrassment of those who attempt to classify and distinguish the new acquisitions, poured in such multitudes into our museums, should increase with the augmentation of their number, is quite natural; since to obviate this it is not enough that our powers of discrimination should keep pace with the increase of the objects, but we ought to possess greater opportunities of studying each animal and plant in all stages of its growth, and to know profoundly their history, their habits, and physiological characters, throughout several generations; for, in proportion as the series of known animals grows more complete, none can doubt that there is a nearer approximation to a graduated scale of being; and thus the most closely allied species will be found to possess a greater number of characters in common.

Causes of the difficulty of discriminating species.— But, in point of fact, our new acquisitions consist, more and more as we advance, of specimens brought from foreign and often very distant and barbarous countries. A large proportion have never even been seen alive by scientific inquirers. Instead of having specimens of the young, the adult, and the aged individuals of each sex, and possessing means of investigating the anatomical structure, the peculiar habits, and instincts of each, what is usually the state of our information? A single specimen, perhaps, of a dried plant, or a stuffed bird or quadruped; a shell, without the soft parts of the animal; an insect in one stage of its numerous transformations;— these are the scanty

and imperfect data which the naturalist possesses. Such information may enable us to separate species which stand at a considerable distance from each other; but we have no right to expect any thing but difficulty and ambiguity, if we attempt, from such imperfect opportunities, to obtain distinctive marks for defining the characters of species which are closely related.

If Lamarck could introduce so much certainty and precision into the classification of several thousand species of recent and fossil shells, notwithstanding the extreme remoteness of the organization of these animals from the type of those vertebrated species which are best known, and in the absence of so many of the living inhabitants of shells, we are led to form an exalted conception of the degree of exactness to which specific distinctions are capable of being carried, rather than to call in question their reality.

When our data are so defective, the most acute naturalist must expect to be sometimes at fault, and, like the novice, to overlook essential points of difference, passing unconsciously from one species to another, until, like one who is borne along in a current, he is astonished, on looking back, at observing that he has reached a point so remote from that whence he set out.

It is by no means improbable, that, when the series of species of certain genera is very full, they may be found to differ less widely from each other than do the mere varieties or races of certain species. If such a fact could be established, it would, undoubtedly, diminish the chance of our obtaining certainty in our results; but it would by no means overthrow our confidence in the reality of species.

Some mere varieties possibly more distinct than certain

individuals of distinct species. — It is almost necessary, indeed, to suppose that varieties will differ in some cases more decidedly than some species, if we admit that there is a graduated scale of being, and assume that the following laws prevail in the economy of the animate creation: — first, that the organization of individuals is capable of being modified to a limited extent by the force of external causes; secondly, that these modifications are, to a certain extent, transmissible to their offspring; thirdly, that there are fixed limits, beyond which the descendants from common parents can never deviate from a certain type; fourthly, that each species springs from one original stock, and can never be permanently confounded by intermixing with the progeny of any other stock; fifthly, that each species shall endure for a considerable period of time. Now, let us assume, for the present, these rules hypothetically, and see what consequences may naturally be expected to result from them.

We must suppose that, when the Author of Nature creates an animal or plant, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself, and survive under all the varying circumstances to which it must be inevitably exposed. Now, the range of variation of circumstances will differ essentially in almost every case. Let us take, for example, any one of the most influential conditions of existence, such as temperature. In some extensive districts near the equator, the thermometer might never vary, throughout several thousand centuries, for more than 20° Fahrenheit; so that if a plant or animal be provided with an organization fitting it to endure such a

range, it may continue on the globe for that immense period, although every individual might be liable at once to be cut off by the least possible excess of heat or cold beyond the determinate degree. But if a species be placed in one of the temperate zones, and have a constitution conferred on it capable of supporting a similar range of temperature only, it will inevitably perish before a single year has passed away.

Humboldt has shown that, at Cumana, within the tropics, there is a difference of only four degrees (Fahr.) between the temperature of the warmest and coldest months; whereas at Quebec and Pekin, in the temperate zones, the annual variation amounts to about 60°.

The same remark might be applied to any other condition, as food, for example: it may be foreseen that the supply will be regular throughout indefinite periods in one part of the world, and in another very precarious and fluctuating both in kind and quantity. Different qualifications may be required for enabling species to live for a considerable time under circumstances so changeable. If, then, temperature and food be among those external causes which, according to certain laws of animal and vegetable physiology, modify the organization, form, or faculties of individuals, we instantly perceive that the degrees of variability from a common standard must differ widely in the two cases above supposed; since there is a necessity of accommodating a species in one case to a much greater latitude of circumstances than in the other.

If it be a law, for instance, that scanty sustenance should check those individuals in their growth which are enabled to accommodate themselves to privations of this kind, and that a parent, prevented in this

manner from attaining the size proper to its species, should produce a dwarfish offspring, a stunted race will arise, as is remarkably exemplified in some varieties of the horse and dog. The difference of stature in some races of dogs, when compared to others, is as one to five in linear dimensions, making a difference of a hundred-fold in volume.* Now, there is good reason to believe that species in general are by no means susceptible of existing under a diversity of circumstances, which may give rise to such a disparity in size, and, consequently, there will be a multitude of distinct species, of which no two adult individuals can ever depart so widely from a certain standard of dimensions as the mere varieties of certain other species — the dog, for instance. Now, we have only to suppose that what is true of size, may also hold in regard to colour and many other attributes; and it will at once follow, that the degree of possible discordance between varieties of the same species may, in certain cases, exceed the utmost disparity which can arise between two individuals of many distinct species.

The same remarks may hold true in regard to instincts; for, if it be foreseen that one species will have to encounter a great variety of foes, it may be necessary to arm it with great cunning and circumspection, or with courage or other qualities capable of developing themselves on certain occasions; such, for example, as those migratory instincts which are so remarkably exhibited at particular periods, after they have remained dormant for many generations. The history and habits of one variety of such a species may often differ more considerably from some other than

* Cuvier, Disc. Prélim., p.128. sixth edition.

those of many distinct species which have no such latitude of accommodation to circumstances.

Extent of known variability in species. — Lamarck has somewhat misstated the idea commonly entertained of a species; for it is not true that naturalists in general assume that the organization of an animal or plant remains absolutely constant, and that it can never vary in any of its parts.* All must be aware that circumstances influence the habits, and that the habits may alter the state of the parts and organs; but the difference of opinion relates to the extent to which these modifications of the habits and organs of a particular species may be carried.

Now, let us first inquire what positive facts can be adduced in the history of known species, to establish a great and permanent amount of change in the form, structure, or instinct of individuals descending from some common stock. The best authenticated examples of the extent to which species can be made to vary may be looked for in the history of domesticated animals and cultivated plants. It usually happens, that those species, both of the animal and vegetable kingdom, which have the greatest pliability of organization, those which are most capable of accommodating themselves to a great variety of new circumstances, are most serviceable to man. These only can be carried by him into different climates, and can have their properties or instincts variously diversified by differences of nourishment and habits. If the resources of a species be so limited, and its habits and faculties be of such a confined and local character, that it can only

* Phil. Zool., tom. i. p. 266.

flourish in a few particular spots, it can rarely be of great utility.

We may consider, therefore, that, in perfecting the arts of domesticating animals and cultivating plants, mankind have first selected those species which have the most flexible frames and constitutions, and have then been engaged for ages in conducting a series of experiments, with much patience and at great cost, to ascertain what may be the greatest possible deviation from a common type which can be elicited in these extreme cases.

Varieties of the dog — no transmutation.— The modifications produced in the different races of dogs exhibit the influence of man in the most striking point of view. These animals have been transported into every climate, and placed in every variety of circumstances; they have been made, as a modern naturalist observes, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius has had a wonderful influence, not only on their forms, but on their manners and intelligence.* Different races have undergone remarkable changes in the quantity and colour of their clothing: the dogs of Guinea are almost naked, while those of the arctic circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads.

But, if we look for some of those essential changes which would be required to lend even the semblance

* Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 63. Sept. 1830.

of a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration of others, we find nothing of the kind. For, in all these varieties of the dog, says Cuvier, the relation of the bones with each other remains essentially the same; the form of the teeth never changes in any perceptible degree, except that, in some individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other.* The greatest departure from a common type—and it constitutes the maximum of variation as yet known in the animal kingdom—is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones; a variety analogous to one presented by six-fingered families of the human race.†

Lamarck has thrown out as a conjecture, that the wolf may have been the original of the dog; but he has adduced no data to bear out such an hypothesis. "The wolf," observes Dr. Prichard, "and the dog differ, not only with respect to their habits and instincts, which in the brute creation are very uniform within the limits of one species; but some differences have also been pointed out in their internal organization, particularly in the structure of a part of the intestinal canal."‡

Domestic animals in South America have reverted to their original character.—It is well known that the horse, the ox, the boar, and other domestic animals, which have been introduced into South America, and have run wild in many parts, have entirely lost all marks of domesticity, and have reverted to the original characters of their species. But dogs have also become

* Disc. Prél., p. 129. sixth edition. † Ibid.

‡ Prichard, Phys. Hist. of Mankind, vol. i. p. 96., who cites Professor Güldenstädt.

wild in Cuba, Hayti, and in all the Caribbean islands. In the course of the seventeenth century, they hunted in packs from twelve to fifty, or more, in number, and fearlessly attacked herds of wild boars and other animals. It is natural, therefore, to inquire to what form they reverted? Now, they are said by many travellers to have resembled very nearly the shepherd's dog; but it is certain that they were never turned into wolves. They were extremely savage, and their ravages appear to have been as much dreaded as those of wolves; but when any of their whelps were caught, and brought from the woods to the towns, they grew up in the most perfect submission to man.

Mummies of animals in Egyptian tombs identical with species still living. — As the advocates of the theory of transmutation trust much to the slow and insensible changes which time may work, they are accustomed to lament the absence of accurate descriptions, and figures of particular animals and plants, handed down from the earliest periods of history, such as might have afforded data for comparing the condition of species, at two periods considerably remote. But, fortunately, we are in some measure independent of such evidence; for, by a singular accident, the priests of Egypt have bequeathed to us, in their cemeteries, that information which the museums and works of the Greek philosophers have failed to transmit.

For the careful investigation of these documents, we are greatly indebted to the skill and diligence of those naturalists who accompanied the French armies during their brief occupation of Egypt: that conquest of four years, from which we may date the improvement of the modern Egyptians in the arts and sciences, and the rapid progress which has been made of late in our

knowledge of the arts and sciences of their remote predecessors. Instead of wasting their whole time, as so many preceding travellers had done, in exclusively collecting human mummies, M. Geoffroy and his associates examined diligently, and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog, the cat, the ape, the ichneumon, the crocodile, and the ibis.

To those who have never been accustomed to connect the facts of Natural History with philosophical speculations, who have never raised their conceptions of the end and import of such studies beyond the mere admiration of isolated and beautiful objects, or the exertion of skill in detecting specific differences, it will seem incredible that amidst the din of arms, and the stirring excitement of political movements, so much enthusiasm could have been felt in regard to these precious remains.

In the official report, drawn up by the Professors of the Museum at Paris, on the value of these objects, there are some eloquent passages, which may appear extravagant, unless we reflect how fully these naturalists could appreciate the bearing of the facts thus brought to light on the past history of the globe.

"It seems," say they, "as if the superstition of the ancient Egyptians had been inspired by Nature, with a view of transmitting to after ages a monument of her history. That extraordinary and whimsical people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what

was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognizable, many an animal, which at Thebes or Memphis, two or three thousand years ago, had its own priests and altars.*

Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles; but, what was perhaps of still higher importance in deciding the great question under discussion, there were the mummies of domestic animals, among which those above mentioned, the bull, the dog, and the cat, were frequent. Now, such was the conformity of the whole of these species to those now living, that there was no more difference, says Cuvier, between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every climate, and forced to accommodate their habits to the greatest variety of circumstances. The cat, for example, has been carried over the whole earth, and, within the last three centuries, has been naturalized in every part of the new world,—from the cold regions of Canada to the tropical plains of Guiana; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians.

Of the ox, undoubtedly, there are many very distinct races: but the bull Apis, which was led in solemn

* Ann. du Muséum d'Hist. Nat., tom. i. p. 234. 1802. The reporters were MM. Cuvier, Lacépède, and Lamarck.

processions by the Egyptian priests, did not differ from some of those now living. The black cattle that have run wild in America, where there were many peculiarities in the climate not to be found, perhaps, in any part of the old world, and where scarcely a single plant on which they fed was of precisely the same species, instead of altering their form and habits, have actually reverted to the exact likeness of the aboriginal wild cattle of Europe.

In answer to the arguments drawn from the Egyptian mummies, Lamarck said that they were identical with their living descendants in the same country, because the climate and physical geography of the banks of the Nile have remained unaltered for the last thirty centuries. But why, it may be asked, have other individuals of these species retained the same characters in so many different quarters of the globe, where the climate and many other conditions are so varied?

Seeds and plants from the Egyptian tombs.— The evidence derived from the Egyptian monuments was not confined to the animal kingdom; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form, but even their colour; so effectual has proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to all the other plants.

Native country of the common wheat.— And here I may observe, that there is an obvious answer to La-

marck's objection, that the botanist cannot point out a country where the common wheat grows wild, unless in places where it may have been derived from neighbouring cultivation.* All naturalists are well aware that the geographical distribution of a great number of species is extremely limited; that it was to be expected that every useful plant should first be cultivated successfully in the country where it was indigenous; and that, probably, every station which it partially occupied, when growing wild, would be selected by the agriculturist as best suited to it when artificially increased. Palestine has been conjectured, by a late writer on the Cerealia, to have been the original habitation of wheat and barley; a supposition which appears confirmed by Hebrew and Egyptian traditions, and by tracing the migrations of the worship of Ceres, as indicative of the migrations of the plant.†

If we are to infer that some one of the wild grasses has been transformed into the common wheat, and that some animal of the genus *canis*, still unreclaimed, has been metamorphosed into the dog, merely because we cannot find the domestic dog, or the cultivated wheat, in a state of nature, we may be next called upon to make similar admissions in regard to the camel; for it seems very doubtful whether any race of this species of quadruped is now wild.

Changes in plants produced by cultivation.—But if agriculture, it will be said, does not supply examples of extraordinary changes of form and organization, the horticulturist can, at least, appeal to facts which may

* Phil. Zool. tom. i. p. 227.

† L'Origine et la Patrie des Céréales, &c., Ann. des Sci. Nat., tom. ix. p. 61.

confound the preceding train of reasoning. The crab has been transformed into the apple; the sloe into the plum: flowers have changed their colour, and become double; and these new characters can be perpetuated by seed: a bitter plant, with wavy sea-green leaves, has been taken from the sea-side, where it grew like wild charlóck; has been transplanted into the garden, lost its saltness, and has been metamorphosed into two distinct vegetables, as unlike each other as is each to the parent plant — the red cabbage and the cauliflower. These, and a multitude of analogous facts, are undoubtedly among the wonders of nature, and attest more strongly, perhaps, the extent to which species may be modified, than any examples derived from the animal kingdom. But in these cases we find that we soon reach certain limits, beyond which we are unable to cause the individuals descending from the same stock to vary; while, on the other hand, it is easy to show that these extraordinary varieties could seldom arise, and could never be perpetuated in a wild state for many generations, under any imaginable combination of accidents. They may be regarded as extreme cases, brought about by human interference, and not as phenomena which indicate a capability of indefinite modification in the natural world.

The propagation of a plant by buds or grafts, and by cuttings, is obviously a mode which nature does not employ; and this multiplication, as well as that produced by roots and layers, seems merely to operate as an extension of the life of an individual, and not as a reproduction of the species such as happens by seed. All plants increased by grafts or layers retain precisely the peculiar qualities of the individual to which they owe their origin, and, like an individual, they

have only a determinate existence; in some cases longer, and in others shorter.* It seems now admitted by horticulturists, that none of our garden varieties of fruit are entitled to be considered strictly permanent, but that they wear out after a time†; and we are thus compelled to resort again to seeds: in which case there is so decided a tendency in the seedings to revert to the original type, that our utmost skill is sometimes baffled in attempting to recover the desired variety.

Varieties of the cabbage.—The different races of cabbages afford, as was admitted, an astonishing example of deviation from a common type; but we can scarcely conceive them to have originated, much less to have lasted for several generations, without the intervention of man. It is only by strong manures that these varieties have been obtained, and in poorer soils they instantly degenerate. If, therefore, we suppose in a state of nature the seed of the wild Brassica oleracea to have been wafted from the sea-side to some spot enriched by the dung of animals, and to have there become a cauliflower, it would soon diffuse its seed to some comparatively sterile soils around, and the offspring would relapse to the likeness of the parent stock, like some individuals which were seen growing, in 1831, on the cornice of old London Bridge.

But if we go so far as to imagine the soil, in the spot first occupied, to be constantly manured by herds of wild animals, so as to continue as rich as that of a garden, still the variety could not be maintained; because we know that each of these races is prone to

* Smith's Introduction to Botany, p. 138. Edit. 1807.

† See Mr. Knight's Observations, Hort. Trans., vol. ii. p. 160.

fecundate others, and gardeners are compelled to exert the utmost diligence to prevent cross-breeds. The intermixture of the pollen of varieties growing in the poorer soil around would soon destroy the peculiar characters of the race which occupied the highly manured tract; for, if these accidents so continually happen, in spite of our care, among the culinary varieties, it is easy to see how soon this cause might obliterate every marked singularity in a wild state.

Besides, it is well known that, although the pampered races which we rear in our gardens for use or ornament may often be perpetuated by seed, yet they rarely produce seed in such abundance, or so prolific in quality, as wild individuals; so that if the care of man were withdrawn, the most fertile variety would always, in the end, prevail over the more sterile.

Similar remarks may be applied to the double flowers, which present such strange anomalies to the botanist. The ovarium, in such cases, is frequently abortive; and the seeds, when prolific, are generally much fewer than where the flowers are single.

Changes caused by soil.—Some curious experiments, recently made on the production of blue instead of red flowers in the Hydrangea hortensis, illustrate the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Varieties of the primrose.—Linnæus was of opinion that the primrose, oxlip, cowslip, and polyanthus, were only varieties of the same species. The majority of modern botanists, on the contrary, consider them to be distinct, although some conceived that the oxlip

might be a cross between the cowslip and the primrose. Mr. Herbert has lately recorded the following experiment: — "I raised from the natural seed of one umbel of a highly manured red cowslip a primrose, a cowslip, oxlips of the usual and other colours, a black polyanthus, a hose-in-hose cowslip, and a natural primrose bearing its flower on a polyanthus stalk. From the seed of that very hose-in-hose cowslip, I have since raised a hose-in-hose primrose. I therefore consider all these to be only local varieties, depending upon soil and situation." * Professor Henslow, of Cambridge, has since confirmed this experiment of Mr. Herbert; so that we have an example, not only of the remarkable varieties which the florist can obtain from a common stock, but of the distinctness of analogous races found in a wild state. †

On what particular ingredient, or quality in the earth, these changes depend, has not yet been ascertained. ‡ But gardeners are well aware that particular plants, when placed under the influence of certain circumstances, are changed in various ways, according to the species; and as often as the experiments are repeated, similar results are obtained. The nature of these results, however, depends upon the species, and they are, therefore, part of the specific character: they exhibit the same phenomena again and again, and indicate certain fixed and invariable relations between the physiological peculiarities of the plant, and the influence of certain external agents. They afford no ground for questioning the instability of species, but

* Hort. Trans., vol. iv. p. 19.

† Loudon's Mag. of Nat. Hist., Sept. 1830, vol. iii. p. 408.

‡ Hort. Trans. vol. iii. p. 173.

rather the contrary: they present us with a class of phenomena which, when they are more thoroughly understood, may afford some of the best tests for identifying species, and proving that the attributes originally conferred endure so long as any issue of the original stock remains upon the earth.

CHAPTER III.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE—*continued.*

Variability of a species compared to that of an individual — Species susceptible of modification may be altered greatly in a short time, and in a few generations; after which they remain stationary — The animals now subject to man had originally an aptitude to domesticity — Acquired peculiarities which become hereditary have a close connexion with the habits or instincts of the species in a wild state (p. 453.) — Some qualities in certain animals have been conferred with a view of their relation to man — Wild elephant domesticated in a few years, but its faculties incapable of further development (p. 461.).

Variability of a species compared to that of an individual. — I ENDEAVOURED, in the last chapter, to show, that a belief in the reality of species is not inconsistent with the idea of a considerable degree of variability in the specific character. This opinion, indeed, is little more than an extension of the idea which we must entertain of the identity of an individual, throughout the changes which it is capable of undergoing.

If a quadruped, inhabiting a cold northern latitude, and covered with a warm coat of hair or wool, be transported to a southern climate, it will often, in the course of a few years, shed a considerable portion of its coat, which it gradually recovers on being again

restored to its native country. Even there the same changes are, perhaps, superinduced to a certain extent by the return of winter and summer. We know that the Alpine hare, (*Lepus variabilis*, Pal.,) and the ermine, or stoat, (*Mustela erminea*, Linn.,) become white during winter, and again obtain their full colour during the warmer season; that the plumage of the ptarmigan undergoes a like metamorphosis in colour and quantity, and that the change is equally temporary. We are aware that, if we reclaim some wild animal, and modify its habits and instincts by domestication, it may, if it escapes, become in a few years nearly as wild and untractable as ever; and if the same individual be again retaken, it may be reduced to its former tame state. A plant is placed in a prepared soil, in order that the petals of its flowers may multiply, and their colour be heightened or changed; if we then withhold our care, the flowers of this same individual become again single. In these, and innumerable other instances, we must suppose that the individual was produced with a certain number of qualities; and, in the case of animals, with a variety of instincts, some of which may or may not be developed according to circumstances, or which, after having been called forth, may again become latent when the exciting causes are removed.

Now, the formation of races seems the necessary consequence of such a capability in individuals to vary, if it be a general law that the offspring should very closely resemble the parent. But, before we can infer that there are no limits to the deviation from an original type which may be brought about in the course of an indefinite number of generations, we ought to have some proof that, in each successive generation,

individuals may go on acquiring an equal amount of new peculiarities, under the influence of equal changes of circumstances. The balance of evidence, however, inclines most decidedly on the opposite side; for in all cases we find that the quantity of divergence diminishes from the first in a very rapid ratio.

Species susceptible of modification may be greatly altered in a few generations.—It cannot be objected, that it is out of our power to go on varying the circumstances in the same manner as might happen in the natural course of events during some great geological cycle. For in the first place, where a capacity is given to individuals to adapt themselves to new circumstances, it does not generally require a very long period for its development; if, indeed, such were the case, it is not easy to see how the modification would answer the ends proposed, for all the individuals would die before new qualities, habits, or instincts were conferred.

When we have succeeded in naturalizing some tropical plant in a temperate climate, nothing prevents us from attempting gradually to extend its distribution to higher latitudes, or to greater elevations above the level of the sea, allowing equal quantities of time, or an equal number of generations, for habituating the species to successive increments of cold. But every husbandman and gardener is aware that such experiments will fail; and we are more likely to succeed in making some plants, in the course of the first two generations, support a considerable degree of difference of temperature than a very small difference afterwards, though we persevere for many centuries.

It is the same if we take any other cause instead of temperature; such as the quality of the food, or the

kind of dangers to which an animal is exposed, or the soil in which a plant lives. The alteration in habits, form, or organization, is often rapid during a short period; but when the circumstances are made to vary further, though in ever so slight a degree, all modification ceases, and the individual perishes. Thus some herbivorous quadrupeds may be made to feed partially on fish or flesh; but even these can never be taught to live on some herbs which they reject, and which would even poison them, although the same may be very nutritious to other species of the same natural order. So, when man uses force or stratagem against wild animals, the persecuted race soon becomes more cautious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations: but let the skill and address of man increase, however gradually, no further variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, howeser indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

Animals now subject to man had originally an aptitude to domesticity.—It has been well observed by M. F. Cuvier and M. Dureau de la Malle, that, unless some animals had manifested in a wild state an aptitude to second the efforts of man, their domestication would never have been attempted. If they had all resembled the wolf, the fox, and the hyæna, the patience of the experimentalist would have been exhausted by innumerable failures before he at last succeeded in obtain-

ing some imperfect results ; so, if the first advantages derived from the cultivation of plants had been elicited by as tedious and costly a process as that by which we now make some slight additional improvement in certain races, we should have remained to this day in ignorance of the greater number of their useful qualities.

Acquired instincts of some animals become hereditary.—It is undoubtedly true, that many new habits and qualities have not only been acquired in recent times by certain races of dogs, but have been transmitted to their offspring. But in these cases it will be observed, that the new peculiarities have an intimate relation to the habits of the animal in a wild state, and therefore do not attest any tendency to departure to an indefinite extent from the original type of the species. A race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico, affords a beautiful illustration of a new hereditary instinct. The mode of attack, observes M. Roulin, which they employ, consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the deer, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank; whereas other hunting-dogs, though of superior strength and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar precautions, they are

often killed by the deer on the spot, the vertebræ of their neck being dislocated by the violence of the shock.*

A new instinct has also become hereditary in a mongrel race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and whatever may be his strength is destroyed in a moment.

Some of our countrymen, engaged of late in conducting one of the principal mining associations in Mexico, that of Real del Monte, carried out with them some English greyhounds of the best breed to hunt the hares which abound in that country. The great platform which is the scene of sport is at an elevation of about nine thousand feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down

* M. Roulin, Ann. des Sci. Nat., tom. xvi. p.16. 1829.

the hares with as much ease as the fleetest of their race in this country.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant, in order to spring with unerring aim. The faculty of the Retriever, however, may justly be regarded as more inexplicable and less easily referrible to the instinctive passions of the species. M. Majendie, says a French writer in a recently published memoir, having learnt that there was a race of dogs in England, which stopped and brought back game of their own accord, procured a pair, and, having obtained a whelp from them, kept it constantly under his eyes, until he had an opportunity of assuring himself that, without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

Such attainments, as well as the habits and dispositions which the shepherd's dog and many others inherit, seem to be of a nature and extent which we can hardly explain by supposing them to be modifications of instincts necessary for the preservation of the species in a wild state. When such remarkable habits appear in races of this species, we may reasonably conjecture that they were given with no other view than for the use of man and the preservation of the dog, which thus obtains protection.

Attributes of animals in their relation to man.—As a general rule, I fully agree with M. F. Cuvier, that, in studying the habits of animals, we must

attempt, as far as possible, to refer their domestic qualities to modifications of instincts which are implanted in them in a state of nature; and that writer has successfully pointed out, in an admirable essay on the domestication of the mammalia, the true origin of many dispositions which are vulgarly attributed to the influence of education alone.* But we should go too far if we did not admit that some of the qualities of particular animals and plants may have been given solely with a view to the connexion which it was foreseen would exist between them and man—especially when we see that connexion to be in many cases so intimate, that the greater number, and sometimes all the individuals of the species which exist on the earth, are in subjection to the human race.

We can perceive in a multitude of animals, especially in some of the parasitic tribes, that certain instincts and organs are conferred for the purpose of defence or attack against some other species. Now, if we are reluctant to suppose the existence of similar relations between man and the instincts of many of the inferior animals, we adopt an hypothesis no less violent, though in the opposite extreme to that which has led some to imagine the whole animate and inanimate creation to have been made solely for the support, gratification, and instruction of mankind.

Many species, most hostile to our persons or property, multiply, in spite of our efforts to repress them; others, on the contrary, are intentionally augmented many hundred-fold in number by our exertions. In such instances, we must imagine the relative resources

* Mém. du Mus. d'Hist. Nat.—Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

of man and of species, friendly or inimical to him, to have been prospectively calculated and adjusted. To withhold assent to this supposition, would be to refuse what we must grant in respect to the economy of Nature in every other part of the organic creation; for the various species of contemporary plants and animals have obviously their relative forces nicely balanced, and their respective tastes, passions, and instincts so contrived, that they are all in perfect harmony with each other. In no other manner could it happen that each species, surrounded, as it is, by countless dangers, should be enabled to maintain its ground for periods of considerable duration.

The docility of the individuals of some of our domestic species, extending, as it does, to attainments foreign to their natural habits and faculties, may, perhaps, have been conferred with a view to their association with man. But, lest species should be thereby made to vary indefinitely, we find that such habits are never transmissible by generation.

A pig has been trained to hunt and point game with great activity and steadiness *; and other learned individuals, of the same species, have been taught to spell; but such fortuitous acquirements never become hereditary, for they have no relation whatever to the exigencies of the animal in a wild state, and cannot, therefore, be developments of any instinctive propensities.

Influence of domestication.— An animal in domes-

* In the New Forest, near Ringwood, Hants, by Mr. Toomer, keeper of Broomy Lodge. I have conversed with witnesses of the fact.

ticity, says M. F. Cuvier, is not essentially in a different situation, in regard to the feeling of restraint, from one left to itself. It lives in society without constraint, because, without doubt, it was a social animal; and it conforms itself to the will of man, because it had a chief, to which, in a wild state, it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals, when left to themselves, form herds more or less numerous; and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which, by its superiority, has become the chief of the herd. Our domestic species had, originally, this sociability of disposition; and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope, to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up; and, when individuals of gregarious species have been accustomed to one master, it is he alone whom they acknowledge as their chief—he only whom they obey. "The elephant allows himself to be directed only by the carnac whom he has adopted; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others; and every body knows how dangerous it is to be in the midst of a herd of cows, in pasturages that

are little frequented, when they have not at their head the keeper who takes care of them."

"Every thing, therefore, tends to convince us, that formerly men were only, with regard to the domestic animals, what those who are particularly charged with the care of them still are — namely, members of the society which these animals form among themselves; and that they are only distinguished, in the general mass by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognizes man as a member, and as the chief of its herd, is a domestic animal. It might even be said, that, from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it." *

But the ingenious author whose observations I have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person, is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed; but, when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, and is subjected to the whole human race. It seems fair to presume, that the capability in the instinct of the horse to be thus modified, was given to enable the species to render greater services to man; and, perhaps, the facility with which many other acquired characters become here-

* Mém. du Mus. d'Hist. Nat.

ditary in various races of the horse, may be explicable only on a like supposition. The amble, for example, a pace to which the domestic races in Spanish America are exclusively trained, has, in the course of several generations, become hereditary, and is assumed by all the young colts before they are broken in.*

It seems, also, reasonable to conclude, that the power bestowed on the horse, the dog, the ox, the sheep, the cat, and many species of domestic fowls, of supporting almost every climate, was given expressly to enable them to follow man throughout all parts of the globe, in order that we might obtain their services, and they our protection. If it be objected that the elephant, which, by the union of strength, intelligence, and docility, can render the greatest services to mankind, is incapable of living in any but the warmest latitudes, we may observe, that the quantity of vegetable food required by this quadruped would render its maintenance in the temperate zone too costly, and in the arctic impossible.

Among the changes superinduced by man, none appear, at first sight, more remarkable than the perfect tameness of certain domestic races. It is well known that, at however early an age we obtain possession of the young of many unreclaimed races, they will retain, throughout life, a considerable timidity and apprehensiveness of danger; whereas, after one or two generations, the descendants of the same stock will habitually place the most implicit confidence in man. There is good reason, however, to suspect that such changes are not without analogy in a state of nature;

* Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 58.

or, to speak more correctly, in situations where man has not interfered.

Thus, Dr. Richardson informs us, in his able history of the habits of North American animals, that, "in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species;* but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and scale the rocks with a speed and agility that baffles pursuit." *

It is probable, therefore, that as man, in diffusing himself over the globe, has tamed many wild races, so, also, he has made many tame races wild. Had some of the larger carnivorous beasts, capable of scaling the rocks, made their way into the North American mountains before our hunters, a similar alteration in the instincts of the sheep would doubtless have been brought about.

Wild elephants domesticated in a few years. — No animal affords a more striking illustration of the principal points which I have been endeavouring to establish, than the elephant; for, in the first place, the wonderful sagacity with which he accommodates himself to the society of man, and the new habits which he contracts, are not the result of time, nor of modifications produced in the course of many generations. These animals will breed in captivity, as is now ascertained, in opposition to the vulgar opinion of many modern naturalists, and in conformity to that of the

* Fauna Boreali-Americana, p. 273.

ancients Ælian and Columella*: yet it has always been the custom, as the least expensive mode of obtaining them, to capture wild individuals in the forests, usually when full grown; and, in a few years after they are taken — sometimes, it is said, in the space of a few months — their education is completed.

Had the whole species been domesticated from an early period in the history of man, like the camel, their superior intelligence would, doubtless, have been attributed to their long and familiar intercourse with the lord of the creation; but we know that a few years is sufficient to bring about this wonderful change of habits; and, although the same individual may continue to receive tuition for a century afterwards, yet it makes no further progress in the general development of its faculties. Were it otherwise, indeed, the animal would soon deserve more than the poet's epithet of "half-reasoning."

From the authority of our countrymen employed in the late Burmese war, it appears, in corroboration of older accounts, that, when elephants are required to execute extraordinary tasks, they may be made to understand that they will receive unusual rewards. Some favourite dainty is shown to them, in the hope of acquiring which the work is done; and so perfectly does the nature of the contract appear to be understood, that the breach of it, on the part of the master, is often attended with danger. In this case, a power has been given to the species to adapt their social instincts to new circumstances with surprising rapidity; but the extent of this change is defined by strict and

* Mr. Corse on the Habits, &c. of the Elephant, Phil. Trans. 1799.

arbitrary limits. There is no indication of a tendency to continued divergence from certain attributes with which the elephant was originally endued—no ground whatever for anticipating that, in thousands of centuries, any material alteration could ever be effected. All that we can infer from analogy is, that some more useful and peculiar races might probably be formed, if the experiment were fairly tried; and that some individual characteristic, now only casual and temporary, might be perpetuated by generation.

In all cases, therefore, where the domestic qualities exist in animals, they seem to require no lengthened process for their development; and they appear to have been wholly denied to some classes, which, from their strength and social disposition, might have rendered great services to man; as, for example, the greater part of the quadrumana. The orang-outang, indeed, which, for its resemblance in form to man, and apparently for no other good reason, has been assumed by Lamarck to be the most perfect of the inferior animals, has been tamed by the savages of Borneo, and made to climb lofty trees, and to bring down the fruit. But he is said to yield to his masters an unwilling obedience, and to be held in subjection only by severe discipline. We know nothing of the faculties of this animal which can suggest the idea that it rivals the elephant in intelligence; much less any thing which can countenance the dreams of those who have fancied that it might have been transmuted into "the dominant race." One of the baboons of Sumatra (*Simia carpolegus*) appears to be more docile, and is frequently trained by the inhabitants to ascend trees, for the purpose of gathering cocoa-nuts; a service in which the animal is very expert. He

selects, says Sir Stamford Raffles, the ripe nuts, with great judgment, and pulls no more than he is ordered.* The capuchin and cacajao monkeys are, according to Humboldt, taught to ascend trees in the same manner, and to throw down fruit on the banks of the lower Orinoco.†

It is for the Lamarckians to explain how it happens that those same savages of Borneo have not themselves acquired, by dint of longing, for many generations, for the power of climbing trees, the elongated arms of the orang, or even the prehensile tails of some American monkeys. Instead of being reduced to the necessity of subjugating stubborn and untractable brutes, we should naturally have anticipated "that their wants would have excited them to efforts, and that continued efforts would have given rise to new organs;" or, rather, to the re-acquisition of organs which, in a manner irreconcileable with the principle of the *progressive* system, have grown obsolete in tribes of men which have such constant need of them.

Recapitulation.—It follows, then, from the different facts which have been considered in this chapter, that a short period of time is generally sufficient to effect nearly the whole change which an alteration of external circumstances can bring about in the habits of a species, and that such capacity of accommodation to new circumstances is enjoyed, in very different degrees, by different species.

Certain qualities appear to be bestowed exclusively with a view to the relations which are destined to

* Linn. Trans., vol. xiii. p. 244.

† Pers. Narr. of Travels to the Equinoctial Regions of the New Continent, in the years 1799—1804.

exist between different species and, among others, between certain species and man; but these latter are always so nearly connected with the original habits and propensities of each species in a wild state, that they imply no indefinite capacity of varying from the original type. The acquired habits derived from human tuition are rarely transmitted to the offspring; and when this happens, it is almost universally the case with those merely which have some obvious connexion with the attributes of the species when in a state of independence.

CHAPTER IV.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE — *continued.*

Phenomena of hybrids — Hunter's opinions — Mules not strictly intermediate between parent species — Hybrid plants — Experiments of Kölreuter and Wiegmann — Vegetable hybrids prolific throughout several generations — Why rare in a wild state (p. 7.) — De Candolle on hybrid plants — The phenomena of hybrids confirm the distinctness of species — Theory of the gradation in the intelligence of animals as indicated by the facial angle (p. 15.) — Tiedemann on the brain of the fœtus in mammalia assuming successively the form of the brain of fish, reptile, and bird — Bearing of this discovery on the theory of progressive development and transmutation (p. 20.) — Recapitulation.

Phenomena of hybrids. — WE have yet to consider another class of phenomena, those relating to the production of hybrids, which have been regarded in a very different light with reference to their bearing on the question of the permanent distinctness of species; some naturalists considering them as affording the strongest of all proofs in favour of the reality of species; others, on the contrary, appealing to them

as countenancing the opposite doctrine, that all the varieties of organization and instinct now exhibited in the animal and vegetable kingdoms may have been propagated from a small number of original types.

In regard to the mammifers and birds, it is found that no sexual union will take place between races which are remote from each other in their habits and organization; and it is only in species that are very nearly allied that such unions produce offspring. It may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the hybrid progeny is sterile, and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation. The principal number of observations and experiments relate to the mixed offspring of the horse and the ass; and in this case it is well established that the he-mule can generate, and the she-mule produce. Such cases occur in Spain and Italy, and much more frequently in the West Indies and New Holland; but these mules have never bred in cold climates, seldom in warm regions, and still more rarely in temperate countries.

The hybrid offspring of the she-ass and the stallion, the γιννος of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare, In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude, but in the figure of the body; whereas, in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. The same naturalist infers, from various experiments respecting cross-breeds between the he-goat and ewe, the dog and she-wolf, the goldfinch and canary-bird, that the male transmits his sex to the greatest number, and that the prepon-

derance of males over females exceeds that which prevails where the parents are of the same species.

Hunter's opinion. — The celebrated John Hunter has observed, that the true distinction of species must ultimately be gathered from their incapacity of propagating with each other, and producing offspring, capable of again continuing itself. He was unwilling, however, to admit that the horse and the ass were of the same species, because some rare instances had been adduced of the breeding of mules, although he maintained that the wolf, the dog, and the jackal were all of one species; because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule, in each case, would breed again with the dog. In these cases, however, it may be observed, that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated; a fact of which I believe no examples are yet recorded, either in regard to mixtures of the horse and ass, or any other of the mammalia.

Should the fact be hereafter ascertained, that two mules can propagate their kind, we must still inquire whether the offspring may not be regarded in the light of a monstrous birth, proceeding from some accidental cause, or, rather, to speak more philosophically, from some general law not yet understood, but which may not be permitted permanently to interfere with those laws of generation by which species may, in general, be prevented from becoming blended. If, for example, we discovered that the progeny of a mule race degenerated greatly, in the first generation, in force, sagacity, or any attribute necessary for its preservation in a state of nature, we might infer that,

like a monster, it is a mere temporary and fortuitous variety. Nor does it seem probable that the greater number of such monsters could ever occur unless obtained by art; for, in Hunter's experiments, stratagem or force was, in most instances, employed to bring about the irregular connexion.*

Mules not strictly intermediate between the parent species. — It seems rarely to happen that the mule offspring is truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments, one of the hybrid pups resembled the wolf much more than the rest of the litter; and we are informed by Wiegmann, that, in a litter lately obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

There is undoubtedly a very close analogy between these phenomena and those presented by the intermixture of distinct races of the same species, both in the inferior animals and in man. Dr. Prichard, in his "Physical History of Mankind," cites examples where the peculiarities of the parents have been transmitted very unequally to the offspring; as where children, entirely white, or perfectly black, have sprung from the union of the European and the negro. Sometimes the colour or other peculiarities of one parent, after having failed to show themselves in the immediate progeny, reappear in a subsequent generation; as where a white child is born of two black parents, the grandfather having been a white.†

* Phil. Trans., 1787. Additional Remarks, Phil. Trans., 1789.
† Prichard, vol. i. p. 217.

The same author judiciously observes that, if different species mixed their breed, and hybrid races were often propagated, the animal world would soon present a scene of confusion; its tribes would be everywhere blended together, and we should perhaps find more hybrid creatures than genuine and uncorrupted races.*

Hybrid plants — Kölreuter's experiments. — The history of the vegetable kingdom has been thought to afford more decisive evidence in favour of the theory of the formation of new and permanent species from hybrid stocks. The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata*, which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a female plant of *N. rustica* was impregnated with the pollen of a male plant of *N. paniculata*. The seed ripened, and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata*, and obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata*.

The plan of impregnation adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma.

Wiegmann's experiments. — The same experiment

* Prichard, vol. i. p. 97.

has since been repeated with success by Wiegmann, who found that he could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times.

The blending of the characters of the parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being intermediate, as in the offspring of the two species of verbascum. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks, that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species, *but they never exhibit characters foreign to both.* A recross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

In general, the success attending the production and perpetuity of hybrids among plants depends, as in the animal kingdom, on the degree of proximity between the species intermarried. If their organization be very remote, impregnation never takes place; if somewhat less distant, seeds are formed, but always imperfect and sterile. The next degree of relationship yields hybrid seedlings, but these are barren; and it is only when the parent species are very nearly allied that the hybrid race may be perpetuated for several generations. Even in this case, the best authenticated examples seem confined to the crossing of hybrids

with individuals of pure breed. In none of the experiments most accurately detailed does it appear that both the parents were mules.

Wiegmann diversified as much as possible his mode of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed; and, instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined; so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

Vegetable hybrids why rare in a wild state.— The same observer saw a good exemplification of the manner in which hybrids may be formed in a state of nature. Some wallflowers and pinks had been growing in a garden, in a dry sunny situation; and their stigmas had been ripened so as to be moist, and to absorb pollen with avidity, although their anthers were not yet developed. These stigmas became impregnated by pollen blown from some other adjacent plants of the same species; but, had they been of different species, and not too remote in their organization, mule races must have resulted.

When, indeed, we consider how busily some insects have been shown to be engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting the red and yellow powder by which the stamens of flowers are covered, loading it on their hind legs, and carrying it to their hive for the purpose of feeding their young! In thus providing for their own progeny, these insects assist materially the process of fructification.* Few persons need be reminded that the stamens in certain plants grow on different blossoms from the pistils; and, unless the summit of the pistil be touched with the fertilizing dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees, chiefly, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther-dust of others, seems almost to realize the converse of the miracle believed by the credulous herdsmen of the Lusitanian mares —

> Ore omnes versæ in Zephyrum, stant rupibus altis,
> Exceptantque leves auras: et sæpe sine ullis
> Conjugiis, vento gravidæ, mirabile dictu.†

But, in the first place, it appears that there is a natural aversion in plants, as well as in animals, to irregular sexual unions; and in most of the successful

* See Barton on the Geography of Plants, p. 67.

† Georg. lib. iii. 273.

experiments in the animal and vegetable world, some violence has been used in order to procure impregnation. The stigma imbibes, slowly and reluctantly, the granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

If we consider the vegetable kingdom generally, it must be recollected that even of the seeds which are well ripened, a great part are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations, even if they were ever produced beyond one generation in a wild state. In the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness, in which hybrids are acknowledged to be deficient.

Centaurea hybrida, a plant which never bears seed, and is supposed to be produced by the frequent intermixture of two well-known species of Centaurea,

grows wild upon a hill near Turin. *Ranunculus lacerus*, also sterile, has been produced accidentally at Grenoble, and near Paris, by the union of two Ranunculi; but this occurred in gardens.*

Mr. Herbert's experiments. — Mr. Herbert, in one of his ingenious papers on mule plants, endeavours to account for their non-occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur have already been made many centuries ago, and have formed the various species of botanists; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species.† But we have no data, as yet, to warrant the conclusion, that a single permanent hybrid race has ever been formed, even in gardens, by the intermarriage of two allied species brought from distant habitations. Until some fact of this kind is fairly established, and a new species, capable of perpetuating itself in a state of perfect independence of man, can be pointed out, it seems reasonable to call in question entirely this hypothetical source of new species. That varieties do sometimes spring up from cross breeds, in a natural way, can hardly be doubted; but they probably die out even more rapidly than races propagated by grafts or layers.

Opinion of De Candolle. — De Candolle, whose opinion on a philosophical question of this kind deserves the greatest attention, has observed, in his Essay on Botanical Geography, that the *varieties* of

* Hon. and Rev. W. Herbert, Hort. Trans., vol. iv. p. 41.

† Ibid.

plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various arguments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, "I can perfectly comprehend, without altogether sharing the opinion, that, where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organized beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute *species*." *

Reality of species confirmed by the phenomena of hybrids. — The most decisive arguments, perhaps, amongst many others, against the probability of the derivation of permanent species from cross-breeds, are to be drawn from the fact alluded to by De Candolle, of species having a close affinity to each other occurring in distinct botanical provinces, or countries inhabited by groups of distinct species of indigenous

* Essai Elémentaire, &c., 3me partie.

plants: for in this case naturalists who are not prepared to go the whole length of the transmutationists, are under the necessity of admitting that, in some cases, species which approach very near to each other in their characters, were so created from their origin; an admission fatal to the idea of its being a general law of nature, that a few original types only should be formed, and that all intermediate races should spring from the intermixture of those stocks.

This notion, indeed, is wholly at variance with all that we know of hybrid generation; for the phenomena entitle us to affirm, that had the types been at first somewhat distant, *no cross-breeds would ever have been produced*, much less those prolific races which we now recognize as distinct species.

In regard, moreover, to the permanent propagation of hybrid races among animals, insuperable difficulties present themselves, when we endeavour to conceive the blending together of the different instincts and propensities of two species, so as to insure the preservation of the intermediate race. The common mule, when obtained by human art, may be protected by the power of man; but, in a wild state, it would not have precisely the same wants either as the horse or the ass: and if, in consequence of some difference of this kind, it strayed from the herd, it would soon be hunted down by beasts of prey, and destroyed.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In the case of the common hive-bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct

instincts.* So also we find that, amongst a most numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of two of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

We might also ask, if a few generic types alone have been *created* among insects, and the intermediate species have proceeded from hybridity, where are those original types, combining, as they ought to do, the elements of all the instincts which have made their appearance in the numerous derivative races? So also in regard to animals of all classes, and of plants; if species in general are of hybrid origin, where are the stocks which combine in themselves the habits, properties, and organs, of which all the intervening species ought to afford us mere modifications?

Recapitulation of the arguments from hybrids. — I shall now conclude this subject by summing up, in a few words, the results to which I have been led by the consideration of the phenomena of hybrids. It appears, that the aversion of individuals of distinct species to the sexual union is common to animals and plants; and that it is only when the species approach near to each other in their organization and habits, that any offspring are produced from their connexion. Mules are of extremely rare occurrence in a state of nature, and

* Intr. to Entom., vol. ii., p. 504. Ed. 1817.

no examples are yet known of their having procreated in a wild state. But it has been proved, that hybrids are not universally sterile, provided the parent stocks have a near affinity to each other, although the continuation of the mixed race, for several generations, appears hitherto to have been obtained only by crossing the hybrids with individuals of pure species; an experiment which by no means bears out the hypothesis that a true hybrid race could ever be permanently established.

Hence we may infer, that aversion to sexual intercourse is, in general, a good test of the distinctness of original stocks, or of *species;* and the procreation of hybrids is a proof of the very near affinity of species. Perhaps, hereafter, the number of generations for which hybrids may be continued, before the race dies out (for it seems usually to degenerate rapidly), may afford the zoologist and botanist an experimental test of the difference in the degree of affinity of allied species.

I may also remark, that if it could have been shown that a single permanent species had ever been produced by hybridity (of which there is no satisfactory proof), it might certainly have lent some countenance to the notions of the ancients respecting the gradual deterioration of created things, but none whatever to Lamarck's theory of their progressive perfectibility; for observations have hitherto shown that there is a tendency in mule animals and plants to degenerate in organization.

It was before remarked, that the theory of progressive development arose from an attempt to ingraft the doctrines of the transmutationists upon one of the most popular generalizations in geology. But modern

geological researches have almost destroyed every appearance of that gradation in the successive groups of animate beings, which was supposed to indicate the slow progress of the organic world from the more simple to the more compound structure. In the more modern formations, we find clear indications that the highest orders of the terrestrial mammalia were fully represented during several successive epochs; but in the monuments which we have hitherto examined of more remote eras, in which there are as yet discovered few fluviatile, and perhaps no lacustrine formations, and, therefore, scarcely any means of obtaining an insight into the zoology of the continents then existing, we have only as yet found one example of a mammiferous quadruped. The recent origin of man, and the absence of all signs of any rational being holding an analogous relation to former states of the animate world, affords one, and the only reasonable argument, in support of the hypothesis of a progressive scheme; but none whatever in favour of the fancied evolution of one species out of another.

Theory of the gradation in intellect as shown by the facial angle.—When the celebrated anatomist, Camper, first attempted to estimate the degrees of sagacity of different animals, and of the races of man, by the measurement of the facial angle, some speculators were bold enough to affirm, that certain simiæ differed as little from the more savage races of men, as these do from the human race in general; and that a scale might be traced from "apes with foreheads villanous low" to the African variety of the human species, and from that to the European. The facial angle was measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower

jaw-bone, and observing the angle which it made with the horizontal line; and it was affirmed, that there was a regular series of such angles from birds to the mammalia.

The gradation from the dog to the monkey was said to be perfect, and from that again to man. One of the ape tribe has a facial angle of 42°; and another, which approximated nearest to man in figure, an angle of 50°. To this succeeds (longo sed proximus intervallo) the head of the African negro, which, as well as that of the Kalmuc, forms an angle of 70°; while that of the European contains 80°. The Roman painters preferred the angle of 95°; and the character of beauty and sublimity, so striking in some works of Grecian sculpture, as in the head of the Apollo, and in the Medusa of Sisocles, is given by an angle which amounts to 100°.*

A great number of valuable facts and curious analogies in comparative anatomy were brought to light during the investigations which were made by Camper, John Hunter, and others, to illustrate this scale of organization; and their facts and generalizations must not be confounded with the fanciful systems which White and others deduced from them.†

That there is some connexion between an elevated and capacious forehead, in certain races of men, and a large development of the intellectual faculties, seems highly probable; and that a low facial angle is frequently accompanied with inferiority of mental powers, is certain; but the attempt to trace a graduated scale of intelligence through the different species of animals

* Prichard's Phys. Hist. of Mankind, vol. i. p. 159.

† Ch. White on the Regular Gradation in Man, &c., 1799.

accompanying the modifications of the form of the skull, is a mere visionary speculation. It has been found necessary to exaggerate the sagacity of the ape tribe at the expense of the dog; and strange contradictions have arisen in the conclusions deduced from the structure of the elephant; some anatomists being disposed to deny the quadruped the intelligence which he really possesses, because they found that the volume of his brain was small in comparison to that of the other mammalia; while others were inclined to magnify extravagantly the superiority of his intellect, because the vertical height of his skull is so great when compared to its horizontal length.

Different races of men are all of one species.—It would be irrelevant to our subject if we were to enter into a farther discussion on these topics; because, even if a graduated scale of organization and intelligence could have been established, it would prove nothing in favour of a tendency, in each species, to attain a higher state of perfection. I may refer the reader to the writings of Blumenbach, Prichard, Lawrence, and others, for convincing proofs that the varieties of form, colour, and organization of different races of men, are perfectly consistent with the generally received opinion, that all the individuals of the species have originated from a single pair; and, while they exhibit in man as many diversities of a physiological nature as appear in any other species, they confirm also the opinion of the slight deviation from a common standard of which species are capable.

The power of existing and multiplying in every latitude, and in every variety of situation and climate, which has enabled the great human family to extend itself over the habitable globe, is partly, says Law-

rence, the result of physical constitution, and partly of the mental prerogative of man. If he did not possess the most enduring and flexible corporeal frame, his arts would not enable him to be the inhabitant of all climates, and to brave the extremes of heat and cold, and the other destructive influences of local situation.* Yet, notwithstanding this flexibility of bodily frame, we find no signs of indefinite departure from a common standard, and the intermarriages of individuals of the most remote varieties are not less fruitful than between those of the same tribe.

Tiedemann on the brain of the fœtus in vertebrated animals.—There is yet another department of anatomical discovery to which I must allude, because it has appeared, to some persons, to afford a distant analogy, at least, to that progressive development by which some of the inferior species may have been gradually perfected into those of more complex organization. Tiedemann found, and his discoveries have been most fully confirmed and elucidated by M. Serres, that the brain of the fœtus, in the highest class of vertebrated animals, assumes, in succession, forms analogous to those which belong to fishes, reptiles, and birds, before it acquires the additions and modifications which are peculiar to the mammiferous tribe. So that, in the passage from the embryo to the perfect mammifer, there is a typical representation, as it were, of all those transformations which the primitive species are supposed to have undergone, during a long series of generations, between the present period and the remotest geological era.

* Lawrence, Lectures on Phys. Zool. and Nat. Hist. of Man, p. 192. Ed. 1823.

If you examine the brain of the mammalia, says M. Serres, at an early stage of uterine life, you perceive the cerebral hemispheres consolidated, as in fish, in two vesicles, isolated one from the other; at a later period, you see them affect the configuration of the cerebral hemispheres of reptiles; still later again, they present you with the forms of those of birds; finally, they acquire, at the era of birth, and sometimes later, the permanent forms which the adult mammalia present.

The cerebral hemispheres, then, arrive at the state which we observe in the higher animals only by a series of successive metamorphoses. If we reduce the whole of these evolutions to four periods, we shall see, that in the first are born the cerebral lobes of fishes; and this takes place homogeneously in all classes. The second period will give us the organization of reptiles; the third, the brain of birds; and the fourth, the complex hemispheres of mammalia.

If we could develop the different parts of the brain of the inferior classes, we should make, in succession, a reptile out of a fish, a bird out of a reptile, and a mammiferous quadruped out of a bird. If, on the contrary, we could starve this organ in the mammalia, we might reduce it successively to the condition of the brain of the three inferior classes.

Nature often presents us with this last phenomenon in monsters, but never exhibits the first. Among the various deformities which organized beings may experience, they never pass the limits of their own classes to put on the forms of the class above them. Never does a fish elevate itself so as to assume the form of the brain of a reptile; nor does the latter ever attain that of birds; nor the bird that of the mammifer.

It may happen that a monster may have two heads; but the conformation of the brain always remains circumscribed narrowly within the limits of its class.*

Bearing of these discoveries on the theory of progressive development. — It will be observed, that these curious phenomena disclose, in a highly interesting manner, the unity of plan that runs through the organization of the whole series of vertebrated animals; but they lend no support whatever to the notion of a gradual transmutation of one species into another; least of all of the passage, in the course of many generations, from an animal of a more simple to one of a more complex structure. On the contrary, were it not for the sterility imposed on monsters, as well as on hybrids in general, the argument to be derived from Tiedemann's discovery, like that deducible from experiments respecting hybridity, would be in favour of the successive *degeneracy*, rather than the perfectibility, in the course of ages, of certain classes of organic beings.

Recapitulation. — For the reasons, therefore, detailed in this and the two preceding chapters, we may draw the following inferences in regard to the reality of *species* in nature: —

1st. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species.

2dly. When the change of situation which they can endure is great, it is usually attended by some modifications of the form, colour, size, structure, or other

* E. R. A. Serres, Anatomie Comparée du Cerveau, illustrated by numerous plates, tome i., 1824.

particulars; but the mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the permanent specific character.

3dly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually; indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature; and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

CHAPTER V.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES.

Analogy of climate not attended with identity of species — Botanical geography — Stations — Habitations — Distinct provinces of indigenous plants — Vegetation of islands — Marine vegetation (p. 29.) — In what manner plants become diffused — Effects of wind, rivers, marine currents — Agency of animals (p. 38.) — Many seeds pass through the stomachs of animals and birds undigested — Agency of man in the dispersion of plants, both voluntary and involuntary (p. 42.) — Its analogy to that of the inferior animals.

Next to determining the question whether species have a real existence, the consideration of the laws which regulate their geographical distribution is a subject of primary importance to the geologist. It is only by studying these laws with attention, by observing the positions which groups of species occupy at present, and inquiring how these may be varied in the course of time by migrations, by changes in physical geography, and other causes, that we can hope to learn whether the duration of species be limited, or in what manner the state of the animate world is affected by the endless vicissitudes of the inanimate.

Different regions inhabited by distinct species.—That different regions of the globe are inhabited by entirely distinct animals and plants, is a fact which has been familiar to all naturalists since Buffon first pointed out the want of *specific* identity between the land quadru-

peds of America and those of the Old World. The same phenomenon has, in later times, been forced in a striking manner upon our attention, by the examination of New Holland, where the indigenous species of animals and plants were found to be, almost without exception, distinct from those known in other parts of the world.

But the extent of this parcelling out of the globe amongst different *nations*, as they have been termed, of plants and animals—the universality of a phenomenon so extraordinary and unexpected, may be considered as one of the most interesting facts clearly established by the advance of modern science.

Scarcely fourteen hundred species of plants appear to have been known and described by the Greeks, Romans, and Arabians. At present, more than three thousand species are enumerated, as natives of our own island.* In other parts of the world there have been collected, perhaps, upwards of seventy thousand species. It was not to be supposed, therefore, that the ancients should have acquired any correct notions respecting what may be called the geography of plants, although the influence of climate on the character of the vegetation could hardly have escaped their observation.

Antecedently to investigation, there was no reason for presuming that the vegetable productions, growing wild in the eastern hemisphere, should be unlike those of the western, in the same latitude; nor that the plants of the Cape of Good Hope should be unlike those of the South of Europe; situations where the climate is little dissimilar. The contrary supposition would have seemed more probable, and we might

* Barton's Lectures on the Geography of Plants, p. 2.

have anticipated an almost perfect identity in the animals and plants which inhabit corresponding parallels of latitude. The discovery therefore, that each separate region of the globe, both of the land and water, is occupied by distinct groups of species, and that most of the exceptions to this general rule may be referred to disseminating causes now in operation, is eminently calculated to excite curiosity, and to stimulate us to seek some hypothesis respecting the first introduction of species which may be reconcileable with such phenomena.

Botanical geography.—A comparison of the *plants* of different regions of the globe affords results more to be depended upon in the present state of our knowledge than those relating to the animal kingdom, because the science of botany is more advanced, and probably comprehends a great proportion of the total number of the vegetable productions of the whole earth. Humboldt, in several eloquent passages of his Personal Narrative, was among the first to promulgate philosophical views on this subject. Every hemisphere, says this traveller, produces plants of different species; and it is not by the diversity of climates that we can attempt to explain why equinoctial Africa has no lauriniæ, and the New World no heaths; why the calceolariæ are found only in the southern hemisphere; why the birds of the continent of India glow with colours less splendid than the birds of the hot parts of America; finally, why the tiger is peculiar to Asia, and the ornithorhynchus to New Holland.*

"We can conceive," he adds, "that a small number of the families of plants, for instance, the musaceæ

* Pers. Nar., vol. v., p. 180.

and the palms, cannot belong to very cold regions, on account of their internal structure and the importance of certain organs; but we cannot explain why no one of the family of melastomas vegetates north of the parallel of thirty degrees; or why no rose-tree belongs to the southern hemisphere. Analogy of climates is often found in the two continents without identity of productions."*

The luminous essay of De Candolle on "Botanical Geography" presents us with the fruits of his own researches and those of Humboldt, Brown, and other eminent botanists, so arranged, that the principal phenomena of the distribution of plants are exhibited in connexion with the causes to which they are chiefly referrible.† "It might not, perhaps, be difficult," observes this writer, "to find two points, in the United States and in Europe, or in equinoctial America and Africa, which present all the same circumstances: as for example, the same temperature, the same height above the sea, a similar soil, an equal dose of humidity; yet nearly all, *perhaps all*, the plants in these two similar localities shall be distinct. A certain degree of analogy, indeed, of aspect, and even of structure, might very possibly be discoverable between the plants of the two localities in question; but the *species* would in general be different. Circumstances, therefore, different from those which now determine the *stations*, have had an influence on the *habitations* of plants."

Stations and habitations of plants. — As I shall frequently have occasion to speak of the *stations* and *habitations* of plants in the technical sense in which

* Pers. Nar., vol. v. p. 180.

† Essai Elémentaire de Géographie Botanique. Extrait du 18me vol. du Dict. des Sci. Nat.

the terms are used in the above passage, I may remind the geologist that station indicates the peculiar nature of the locality where each species is accustomed to grow, and has reference to climate, soil, humidity, light, elevation above the sea, and other analogous circumstances; whereas, by habitation is meant a general indication of the country where a plant grows wild. Thus the *station* of a plant may be a salt-marsh, in a temperate climate, a hill-side, the bed of the sea, or a stagnant pool. Its *habitation* may be Europe, North America, or New Holland between the tropics. The study of stations has been styled the topography, that of habitations the geography, of botany. The terms thus defined, express each a distinct class of ideas, which have been often confounded together, and which are equally applicable in zoology.

In further illustration of the principle above alluded to, that difference of longitude, independently of any influence of temperature, is accompanied by a great, and sometimes a complete diversity in the species of plants, De Candolle observes, that, out of 2891 species of phænogamous plants described by Pursh, in the United States, there are only 385 which are found in northern or temperate Europe. MM. Humboldt and Bonpland, in all their travels through equinoctial America, found only twenty-four species (these being all cyperacea and graminea) common to America and any part of the Old World. On comparing New Holland with Europe, Mr. Brown ascertained that, out of 4100 species, discovered in Australia, there were only 166 common to Europe, and of this small number there were some few which may have been transported thither by man.

But it is still more remarkable, that in the more

widely separated parts of the ancient continent, notwithstanding the existence of an uninterrupted land-communication, the diversity in the specific character of the respective vegetations is almost as striking. Thus there is found one assemblage of species in China, another in the countries bordering the Black Sea and the Caspian, a third in those surrounding the Mediterranean, a fourth in the great platforms of Siberia and Tartary, and so forth.

The distinctness of the groups of indigenous plants, in the same parallel of latitude, is greatest where continents are disjoined by a wide expanse of ocean. In the northern hemisphere, near the pole, where the extremities of Europe, Asia, and America unite or approach near to one another, a considerable number of the same species of plants are found, common to the three continents. But it has been remarked, that these plants, which are thus so widely diffused in the Arctic regions, are also found in the chain of the Aleutian islands, which stretch almost across from America to Asia, and which may probably have served as the channel of communication for the partial blending of the Floras of the adjoining regions. It has, indeed, been found to be a general rule, that plants found at two points very remote from each other, occur also in places intermediate.

Vegetation of islands. — In islands very distant from continents the total number of plants is comparatively small; but a large proportion of the species are such as occur nowhere else. In so far as the Flora of such islands is not peculiar to them, it contains, in general, species common to the nearest main lands.*

* Prichard, vol. i. p. 36. Brown, Appendix to Flinders.

The islands of the great southern ocean exemplify these rules; the easternmost containing more American, and the western more Indian plants.* Madeira and Teneriffe contain many species, and even entire genera, peculiar to them; but they have also plants in common with Portugal, Spain, the Azores, and the north-west coast of Africa.†

In the Canaries, out of 533 species of phænogamous plants, it is said that 310 are peculiar to these islands, and the rest identical with those of the African continent; but in the Flora of St. Helena, which is so far distant even from the western shores of Africa, there have been found, out of sixty-one native species, only *two or three* which are to be found in any other part of the globe.

Number of botanical provinces.— De Candolle has enumerated twenty great botanical provinces inhabited by indigenous or aboriginal plants; and although many of these contain a variety of species which are common to several others, and sometimes to places very remote, yet the lines of demarcation are, upon the whole, astonishingly well defined.‡ Nor is it likely that the bearing of the evidence on which these general views are founded will ever be materially affected, since they are already confirmed by the examination of seventy or eighty thousand species of plants.

The entire change of opinion which the contemplation of these phenomena has brought about is worthy

* Forster, Observations, &c.

† Humboldt, Pers. Nar., vol. i. p. 270. of the translation. Prichard, Phys. Hist. of Mankind, vol. i. p. 37.

‡ See a farther subdivision, by which twenty-seven provinces are made, by M. Alph. De Candolle, son of De Candolle. Monogr. des Campanulées. Paris, 1830.

of remark. The first travellers were persuaded that they should find, in distant regions, the plants of their own country, and they took a pleasure in giving them the same names. It was some time before this illusion was dissipated; but so fully sensible did botanists at last become of the extreme smallness of the number of phænogamous plants common to different continents, that the ancient Floras fell into disrepute. All grew diffident of the pretended identifications; and we now find that every naturalist is inclined to examine each supposed exception with scrupulous severity.* If they admit the fact, they begin to speculate on the mode whereby the seeds may have been transported from one country into the other, or inquire on which of two continents the plant was indigenous, assuming that a species, like an individual, cannot have two birth-places.

Marine vegetation. — The marine vegetation is less known; but we learn from Lamouroux, that it is divisible into different systems, apparently as distinct as those on the land, notwithstanding that the uniformity of temperature is so much greater in the ocean. For on that ground we might have expected the phenomenon of partial distribution to have been far less striking, since climate is, in general, so influential a cause in checking the dispersion of species from one zone to another.

The number of hydrophytes, as they are termed, is very considerable, and their stations are found to be infinitely more varied than could have been anticipated; for while some plants are covered and uncovered daily by the tide, others live in abysses of the ocean, at the

* De Candolle, Essai Elémen. de Géog. Botan., p. 45.

extraordinary depth of one thousand feet: and although in such situations there must reign darkness more profound than night, at least to our organs, many of these vegetables are highly coloured. From the analogy of terrestrial plants we might have inferred, that the colouring of the algæ was derived from the influence of the solar rays; yet we are compelled to doubt when we reflect how feeble must be the rays which penetrate to these great depths.

The subaqueous vegetation of the Mediterranean is, upon the whole, distinct from that of the Atlantic on the west, and that part of the Arabian gulf which is immediately contiguous on the south. Other botanical provinces are found in the West Indian seas, including the gulf of Mexico; in the ocean which washes the shores of South America; in the Indian Ocean and its gulfs; in the seas of Australia; and in the Atlantic basin, from the 40th degree of north latitude to the pole. There are very few species common to the coast of Europe and the United States of North America, and none common to the Straits of Magellan and the shores of Van Diemen's Land.

It must not be overlooked, that the distinctness alluded to between the vegetation of these several countries relates strictly to *species*, and not to forms. In regard to the numerical preponderance of certain forms, and many peculiarities of internal structure, there is a marked agreement in the vegetable productions of districts placed in corresponding latitudes, and under similar physical circumstances, however remote their position. Thus there are innumerable points of analogy between the vegetation of the Brazils, equinoctial Africa, and India; and there are also points of difference wherein the plants of these regions are dis-

tinguishable from all extra-tropical groups. But there are very few species common to the three continents. The same may be said, if we compare the plants of the Straits of Magellan with those of Van Diemen's Land, or the vegetation of the United States with that of the middle of Europe: the species are distinct, but the forms are in a great degree analogous.

Let us now consider what means of diffusion, independently of the agency of man, are possessed by plants, whereby, in the course of ages, they may be enabled to stray from one of the botanical provinces above mentioned to another, and to establish new colonies at a great distance from their birth-place.

Manner in which plants become diffused.— Winds.— The principal of the inanimate agents provided by nature for scattering the seeds of plants over the globe, are the movements of the atmosphere and of the ocean, and the constant flow of water from the mountains to the sea. To begin with the winds: a great number of seeds are furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Other plants are fitted for dispersion by means of an attached wing, as in the case of the fir-tree, so that they are caught up by the wind as they fall from the cone, and are carried to a distance. Amongst the comparatively small number of plants known to Linnæus, no less than 138 genera are enumerated as having winged seeds.

As winds often prevail for days, weeks, or even months together, in the same direction, these means of transportation may sometimes be without limits; and even the heavier grains may be borne through con-

siderable spaces, in a very short time, during ordinary tempests; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour, and if the storm be very violent, at the rate of fifty-six miles.* The hurricanes of tropical regions, which root up trees and throw down buildings, sweep along at the rate of ninety miles an hour; so that, for however short a time they prevail, they may carry even the heavier fruits and seeds over friths and seas of considerable width, and doubtless, are often the means of introducing into islands the vegetation of adjoining continents. Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields, in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees, and carry them up in a whirling column of air.

Franklin tells us, in one of his letters, that he saw, in Maryland, a whirlwind which began by taking up the dust which lay in the road, in the form of a sugar-loaf with the pointed end downwards, and soon after grew to the height of forty or fifty feet, being twenty or thirty in diameter. It advanced in a direction contrary to the wind; and although the rotatory motion of the column was surprisingly rapid, its onward progress was sufficiently slow to allow a man to keep pace with it on foot. Franklin followed it on horseback, accompanied by his son, for three-quarters of a mile, and saw it enter a wood, where it twisted and turned

* Annuaire du Bureau des Longitudes.

round large trees with surprising force. These were carried up in a spiral line, and were seen flying in the air, together with boughs and innumerable leaves, which, from their height, appeared reduced to the apparent size of flies. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but insects, land-testacea and their eggs, with many other species of animals, to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

Distribution of cryptogamous plants.—It has been found that a great numerical proportion of the exceptions to the limitation of species to certain quarters of the globe, occur in the various tribes of cryptogamic plants. Linnæus observed that, as the germs of plants of this class, such as mosses, fungi, and lichens, consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, there is no difficulty to account for their being dispersed throughout the atmosphere, and carried to every point of the globe, where there is a station fitted for them. Lichens in particular ascend to great elevations, sometimes growing two thousand feet above the line of perpetual snow, at the utmost limits of vegetation, and where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists.*

Some have inferred, from the springing up of mushrooms whenever particular soils and decomposed or-

* Linn., Tour in Lapland, vol. ii. p. 282.

ganic matter are mixed together, that the production of fungi is accidental, and not analogous to that of perfect plants.* But Fries, whose authority on these questions is entitled to the highest respect, has shown the fallacy of this argument in favour of the old doctrine of equivocal generation. "The sporules of fungi," says this naturalist, "are so infinite, that in a single individual of Reticularia maxima, I have counted above ten millions, and so subtile as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded."

Agency of rivers and currents.—In considering, in the next place, the instrumentality of the aqueous agents of dispersion, I cannot do better than cite the words of one of our ablest botanical writers. "The mountain stream or torrent," observes Keith, "washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany; and the western shores of the Atlantic by seeds that have been generated in the interior of America."† Fruits,

* Lindley, Introd. to Nat. Syst. of Botany, who cites Fries.

† System of Physiological Botany, vol. ii. p. 405.

moreover, indigenous to America and the West Indies, such as that of the Mimosa scandens, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf stream, on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the Guilandina Bonduc, a leguminous plant, is particularly mentioned, as having been raised from a seed found on the west coast of Ireland.*

Sir Hans Sloane states, that several kinds of beans cast ashore on the Orkney Isles, and the coast of Ireland, are derived from trees which grow in the West Indies, and many of them in Jamaica. He conjectures that they may have been conveyed by rivers into the sea, and then by the Gulf stream to greater distances, in the same manner as the sea-weed called Lenticula marina, or Sargasso, which grows on the rocks about Jamaica, is known to be "carried by the winds and current towards the coast of Florida, and thence into the North American ocean, where it lies very thick on the surface of the sea."†

The absence of liquid matter in the composition of seeds renders them comparatively insensible to heat and cold, so that they may be carried without detriment through climates where the plants themselves would instantly perish. Such is their power of resisting the effects of heat, that Spallanzani mentions some seeds that germinated after having been boiled in water.‡ When, therefore, a strong gale, after blowing violently off the land for a time, dies away,

* Brown, Append. to Tuckey, No. V. p. 481.

† Phil. Trans., 1696.

‡ System of Physiological Botany, vol. ii. p. 403.

and the seeds alight upon the surface of the waters, or wherever the ocean, by eating away the sea-cliffs, throws down into its waves plants which would never otherwise approach the shores, the tides and currents become active instruments in assisting the dissemination of almost all classes of the vegetable kingdom.

In a collection of six hundred plants from the neighbourhood of the river Zaire, in Africa, Mr. Brown found that thirteen species were also met with on the opposite shores of Guiana and Brazil. He remarked that most of these plants were found only on the lower parts of the river Zaire, and were chiefly such as produced seeds capable of retaining their vitality a long time in the currents of the ocean.

The migration of plants aided by islands.—Islands, moreover, and even the smallest rocks, play an important part in aiding such migrations; for when seeds alight upon them from the atmosphere, or are thrown up by the surf, they often vegetate, and supply the winds and waves with a repetition of new and uninjured crops of fruit and seeds. These may afterwards pursue their course through the atmosphere, or along the surface of the sea, in the same direction. The number of plants found at any given time on an islet affords us no test whatever of the extent to which it may have co-operated towards this end, since a variety of species may first thrive there and then perish, and be followed by other chance-comers like themselves.

Currents and winds in the arctic regions drift along icebergs covered with an alluvial soil on which herbs and pine-saplings are seen growing, which may often continue to vegetate on some distant shore where the ice-island is stranded.

Dispersion of marine plants.—With respect to marine vegetation, the seeds, being in their native element, may remain immersed in water without injury for indefinite periods, so that there is no difficulty in conceiving the diffusion of species wherever uncongenial climates, contrary currents, and other causes, do not interfere. All are familiar with the sight of the floating sea-weed,

"Flung from the rock on ocean's foam to sail,
Where'er the surge may sweep, the tempest's breath prevail."

Remarkable accumulations of that species of seaweed generally known as gulf-weed, or sargasso, occur on each side of the equator in the Atlantic, Pacific, and Indian Oceans. Columbus and other navigators, who first encountered these banks of algæ in the Northern Atlantic, compared them to vast inundated meadows, and state that they retarded the progress of their vessels. The most extensive bank is a little west of the meridian of Fayal, one of the Azores, between latitudes 35° and 36°: violent north winds sometimes prevail in this space, and drive the seaweed to low latitudes, as far as the 24th or even the 20th degree.*

The hollow pod-like receptacles in which the seeds of many algæ are lodged, and the filaments attached to the seed-vessels of others, seem intended to give buoyancy; and I may observe that these hydrophytes are in general *proliferous*, so that the smallest fragment of a branch can be developed into a perfect plant. The seeds, moreover, of the greater number of species are enveloped with a mucous matter like that which

* Greville, Introduction to Algæ Britannicæ, p. 12.

surrounds the eggs of some fish, and which not only protects them from injury, but serves to attach them to floating bodies or to rocks.

Agency of animals in the distribution of plants.— But we have as yet considered part only of the fertile resources of nature for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs, to the coats of animals, or feathers of the winged tribe, to which they remain attached for weeks, or even months, and are borne along into every region whither birds or quadrupeds may migrate. Linnæus enumerates fifty genera of plants, and the number now known to botanists is much greater, which are armed with hooks, by which, when ripe, they adhere to the coats of animals. Most of these vegetables, he remarks, require a soil enriched with dung. Few have failed to mark the locks of wool hanging on the thorn-bushes, wherever the sheep pass, and it is probable that the wolf or lion never give chase to herbivorous animals without being unconsciously subservient to this part of the vegetable economy.

A deer has strayed from the herd when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly takes to flight, dashing through many a thicket, and swimming across many a river and lake. The seeds of the herbs and shrubs which have adhered to his smoking flanks, are washed off again by the waters. The thorny spray is torn off, and fixes itself in his hairy coat, until brushed off again in other thickets and copses. Even on the

spot where the victim is devoured many of the seeds which he had swallowed immediately before the chase may be left on the ground uninjured, and ready to spring up in a new soil.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants, and is of all others, perhaps, the most likely to be overlooked. Few are ignorant that a portion of the oats eaten by a horse preserve their germinating faculty in the dung. The fact of their being still nutritious is not lost on the sagacious rook. To many, says Linnæus, it seems extraordinary, and something of a prodigy, that when a field is well tilled and sown with the best wheat, it frequently produces darnel or the wild oat, especially if it be manured with new dung: they do not consider that the fertility of the smaller seeds is not destroyed in the stomachs of animals.*

Agency of birds. — Some birds of the order Passeres devour the seeds of plants in great quantities, which they eject again in very distant places, without destroying its faculty of vegetation; thus a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot trefoil (*Medicago lupulina*), and others whose seeds are so heavy that the wind is not able to scatter them to any distance.† In like manner, the blackbird and misselthrush, when they devour berries in too great quantities, are known to consign them to the earth undigested in their excrement.‡

* Linnæus, Amœn. Acad., vol. ii. p. 409.
† Amœn. Acad., vol. iv. Essay 75. § 8.
‡ Ibid., vol. vi. § 22.

Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth in a condition peculiarly fit for vegetation.* So well are the farmers, in some parts of England, aware of this fact, that when they desire to raise a quick-set hedge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Cratægus Oxyacantha*), and then sow the stones which are ejected in their excrement, whereby they gain an entire year in the growth of the plant.† Birds when they pluck cherries, sloes, and haws, fly away with them to some convenient place; and when they have devoured the fruit, drop the stone into the ground. Captain Cook, in his account of the volcanic island of Tanna, one of the New Hebrides, which he visited in his second voyage, makes the following interesting observation:—"Mr. Forster, in his botanical excursion this day, shot a pigeon, in the craw of which was a wild nutmeg. He took some pains to find the tree on this island, but his endeavours were without success."‡ It is easy, therefore, to perceive, that birds in their migrations to great distances, and even across seas, may transport seeds to new isles and continents.

The sudden deaths to which great numbers of frugivorous birds are annually exposed must not be omitted as auxiliary to the transportation of seeds to new habitations. When the sea retires from the shore,

* Smith's Introd. to Phys. and Syst. Botany, p. 304. 1807.

† This information was communicated to me by Professor Henslow, of Cambridge.

‡ Book iii. ch. iv.

and leaves fruits and seeds on the beach, or in the mud of estuaries, it might, by the returning tide, wash them away again, or destroy them by long immersion; but when they are gathered by land birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland; and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, or a thousand years, it will be sufficient to spread many of the plants from one continent to another; for, in estimating the activity of these causes, we must not consider whether they act slowly in relation to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connexion with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the oceanic current drifts them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey, the unpalatable seeds to spring up and flourish in a new soil.

The machinery before adverted to is so capable of disseminating seeds over almost unbounded spaces, that were we more intimately acquainted with the economy of nature, we might probably explain all the instances which occur of the aberration of plants to great distances from their native countries. The real difficulty which must present itself to every one who contemplates the present geographical distribution of species, is the small number of exceptions to the rule of the non-intermixture of different groups of plants.

Why have they not, supposing them to have been ever so distinct originally, become more blended and confounded together in the lapse of ages?

Agency of man in the dispersion of plants.—But in addition to all the agents already enumerated as instrumental in diffusing plants over the globe, we have still to consider man—one of the most important of all. He transports with him, into every region, the vegetables which he cultivates for his wants; and is the involuntary means of spreading a still greater number which are useless to him, or even noxious. "When the introduction of cultivated plants is of recent date, there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize or the potato; nor the origin, in the old world, of the coffee-tree, and of wheat. But there are certain objects of culture, of very ancient date, between the tropics, such, for example, as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry, in all directions, grain and cultivated vegetables from one extremity of Europe to the other; and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the crusades, may have transported many plants from one part of the world to the other."*

But, besides the plants used in agriculture, the number which have been naturalized by accident, or which man has spread unintentionally, is considerable. One of our old authors, Josselyn, gives a catalogue of

* De Candolle, Essai Elémen. &c., p. 50.

such plants as had, in his time, sprung up in the colony since the English planted and kept cattle in New England. They were two-and-twenty in number. The common nettle was the first which the settlers noticed; and the plantain was called by the Indians "Englishman's foot," as if it sprung from their footsteps.*

"We have introduced everywhere," observes De Candolle, "some weeds which grow among our various kinds of wheat, and which have been received, perhaps, originally from Asia along with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalize themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool *after it has been washed*. There hardly passes a year without foreign plants being found naturalized in this drying-ground. I have gathered there Centaurea parviflora, Psoralea palæstina, and Hypericum crispum." This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals.

The same botanist mentions instances of plants naturalized in seaports by the ballast of ships; and several examples of others which have spread through Europe from botanical gardens, so as to have become more common than many indigenous species.

It is scarcely a century, says Linnæus, since the

* Quarterly Review, vol. xxx. p. 8.

Canadian erigeron, or flea-bane, was brought from America to the botanical garden at Paris; and already the seeds have been carried by the winds, so that it is diffused over France, the British islands, Italy, Sicily, Holland, and Germany.* Several others are mentioned by the Swedish naturalist, as having been dispersed by similar means. The common thorn-apple (*Datura Stramonium*), observes Willdenow, now grows as a noxious weed throughout all Europe, with the exception of Sweden, Lapland, and Russia. It came from the East Indies and Abyssinia to us, and was so universally spread by certain quacks who used its seed as an emetic.†

In hot and ill-cultivated countries, such naturalizations take place more easily. Thus the Chenopodium ambrosioides, sown by Mr. Burchell on a point of St. Helena, multiplied so in four years as to become one of the commonest weeds in the island.‡

The most remarkable proof, says De Candolle, of the extent to which man is unconsciously the instrument of dispersing and naturalizing species, is found in the fact, that in New Holland, America, and the Cape of Good Hope, the aboriginal European species exceed in number all the others which have come from any distant regions; so that, in this instance, the influence of man has surpassed that of all the other causes which tend to disseminate plants to remote districts.

Although we are but slightly acquainted, as yet, with the extent of our instrumentality in naturalizing species, yet the facts ascertained afford no small reason to suspect, that the number which we introduce

* Essay on the Habitable Earth, Amœn. Acad., vol. ii. p. 409.
† Principles of Botany, p. 389. ‡ Ibid.

unintentionally exceeds all those transported by design. Nor is it unnatural to suppose that the functions, which the inferior beings, extirpated by man, once discharged in the economy of nature, should devolve upon the human race. If we drive many birds of passage from different countries, we are probably required to fulfil their office of carrying seeds, eggs of fish, insects, molluscs, and other creatures, to distant regions; if we destroy quadrupeds, we must replace them, not merely as consumers of the animal and vegetable substances which they devoured, but as disseminators of plants, and of the inferior classes of the animal kingdom. I do not mean to insinuate that the very same changes which man brings about would have taken place by means of the agency of other species, but merely that he supersedes a certain number of agents; and so far as he disperses plants unintentionally, or against his will, his intervention is strictly analogous to that of the species so extirpated.

I may observe, moreover, that if, at former periods, the animals inhabiting any given district have been partially altered by the extinction of some species, and the introduction of others, whether by new creations or by immigration, a change must have taken place in regard to the particular plants conveyed about with them to foreign countries. As, for example, when one set of migratory birds is substituted for another, the countries from and to which seeds are transported are immediately changed. Vicissitudes, therefore, analogous to those which man has occasioned, may have previously attended the springing up of new relations between species in the vegetable and animal worlds.

It may also be remarked, that if man is the most active agent in enlarging, so also is he in circumscribing the geographical boundaries of particular plants. He promotes the migration of some, he retards that of other species, so that, while in many respects he appears to be exerting his power to blend and confound the various provinces of indigenous species, he is, in other ways, instrumental in obstructing the fusion into one group of the inhabitants of contiguous provinces.

Thus, for example, when two botanical regions exist in the same great continent, such as *the European region*, comprehending the central parts of Europe and those surrounding the Mediterranean, and *the Oriental region*, as it has been termed, embracing the countries adjoining the Black Sea and the Caspian, the interposition between these of thousands of square miles of cultivated lands, opposes a new and powerful barrier against the mutual interchange of indigenous plants. Botanists are well aware that garden plants naturalize and diffuse themselves with great facility in comparatively unreclaimed countries, but spread themselves slowly and with difficulty in districts highly cultivated. There are many obvious causes for this difference: by drainage and culture the natural variety of stations is diminished, and those stray individuals by which the passage of a species from one fit station to another is effected, are no sooner detected by the agriculturist, than they are uprooted as weeds. The larger shrubs and trees, in particular, can scarcely ever escape observation, when they have attained a certain size, and will rarely fail to be cut down if unprofitable.

The same observations are applicable to the inter-

change of the insects, birds, and quadrupeds of two regions situated like those above alluded to. No beasts of prey are permitted to make their way across the intervening arable tracts. Many birds, and hundreds of insects, which would have found some palatable food amongst the various herbs and trees of the primeval wilderness, are unable to subsist on the olive, the vine, the wheat, and a few trees and grasses favoured by man. In addition, therefore, to his direct intervention, man, in this case, operates indirectly to impede the dissemination of plants, by intercepting the migrations of animals, many of which would otherwise have been active in transporting seeds from one province to another.

Whether, in the vegetable kingdom, the influence of man will tend, after a considerable lapse of ages, to render the geographical range of *species in general* more extended, as De Candolle seems to anticipate, or whether the compensating agency above alluded to, will not counterbalance the exceptions caused by our naturalizations, admits at least of some doubt. In the attempt to form an estimate on this subject, we must be careful not to underrate, or almost overlook, as some appear to have done, the influence of man in checking the diffusion of plants, and restricting their distribution to narrower limits.

CHAPTER VI.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES—*continued.*

Geographical distribution of animals — Buffon on specific distinctness of quadrupeds of old and new world — Different regions of indigenous mammalia — Quadrupeds in islands — Range of the Cetacea — Dispersion of quadrupeds (p. 54.) — their powers of swimming — Migratory instincts — Drifting of animals on ice-floes (p. 61.) — On floating islands of drift-timber — Migrations of Cetacea — Habitations of birds (p. 67.) — Their migrations and facilities of diffusion — Distribution of reptiles, and their powers of dissemination.

Geographical distribution of animals. — ALTHOUGH in speculating on "philosophical possibilities," said Buffon, "the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar to those previously known in the old world. The elephant, the rhinoceros, the hippopotamus, the camelopard, the camel, the dromedary, the buffalo, the horse, the ass, the lion, the tiger, the apes, the baboons, and a number of other mammalia, were nowhere to be met with on the new continent; while in the old, the American species, of the same great class, were nowhere to be

seen — the tapir, the lama, the pecari, the jaguar, the couguar, the agouti, the paca, the coati, and the sloth."

These phenomena, although few in number relatively to the whole animate creation, were so striking and so positive in their nature, that the great French naturalist caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers. It was, therefore, in a truly philosophical spirit that, relying on the clearness of the evidence obtained respecting the larger quadrupeds, he ventured to call in question the identifications announced by some contemporary naturalists of species of animals said to be common to the southern extremities of America and Africa.*

Causes which prevent the migration of animals.—The migration of quadrupeds from one part of the globe to another, observes one of our ablest writers, is prevented by uncongenial climates and the branches of the ocean which intersect continents. "Hence, by a reference to the geographical site of countries, we may divide the earth into a certain number of regions fitted to become the abodes of particular groups of animals, and we shall find, on inquiry, that each of these provinces, thus conjecturally marked out, is actually inhabited by a distinct nation of quadrupeds."†

Where the continents of the old and new world approximate to each other towards the north, the nar-

* Buffon, vol. v. — On the Virginian Opossum.

† Prichard's Phys. Hist. of Mankind, vol. i. p. 54. In some of the preliminary chapters will be found a sketch of the leading acts illustrative of the geographical distribution of animals, drawn up with the author's usual clearness and ability.

row straits which separate them are frozen over in winter, and the distance is further lessened by intervening islands. Thus a passage from one continent to another becomes practicable to such quadrupeds as are fitted to endure the intense cold of the arctic circle. Accordingly, the whole arctic region has become one of the provinces of the animal kingdom, and contains many species common to both the great continents. But the temperate regions of America, which are separated by a wide extent of ocean from those of Europe and Asia, contain each a distinct nation of indigenous quadrupeds. There are three groups of *tropical* mammalia belonging severally to America, Africa, and continental India, each inhabiting lands separated from each other by the ocean.

In Peru and Chili, says Humboldt, the region of the grasses, which is at an elevation of from 12,300 to 15,400 feet, is inhabited by crowds of lama, guanaco, and alpaca. These quadrupeds, which here represent the genus camel of the ancient continent, have not extended themselves either to Brazil or Mexico; because, during their journey, they must necessarily have descended into regions that were too hot for them.*

Animals in New Holland.—New Holland is well known to contain a most singular and characteristic assemblage of mammiferous animals, consisting of more than forty species of the marsupial family, or those furnished with a pouch under the belly for their young, of which scarcely any congeners occur elsewhere, except a few species in some islands of the Indian archipelago and the opossums of America. There are, it appears, some examples of marsupial animals in the

* Description of the Equatorial Regions.

eastern hemisphere out of the Australian continent. Thus the Phalangista vulpina inhabits both Sumatra and New Holland; the P. ursina is found in the island of Celebes; P. chrysorrhos, in the Moluccas; P. maculata, and P. cavifrons, in Banda and Amboyna.*

This almost exclusive occupation of the Australian continent by the kangaroos and other tribes of pouched animals, although it has justly excited great attention, is a fact, nevertheless, in strict accordance with the general laws of the distribution of species; since, in other parts of the globe, we find peculiarities of form, structure, and habit, in birds, reptiles, insects, or plants, confined entirely to one hemisphere, or one continent, and sometimes to much narrower limits.

In the south of Africa.—The southern region of Africa, where that continent extends into the temperate zone, constitutes another separate zoological province, surrounded as it is on three sides by the ocean, and cut off from the countries of milder climate, in the northern hemisphere, by the intervening torrid zone. In many instances, this region contains the same genera which are found in temperate climates to the northward of the line: but then the southern are different from the northern species. Thus, in the south we find the quagga and the zebra; in the north, the horse, the ass, and the jiggetai of Asia.

The south of Africa is spread out into fine level plains from the tropic to the Cape; in this region, says Pennant, besides the horse genus, of which five species have been found, there are also peculiar species of rhinoceros, the hog, and the hyrax, among pachyder-

* Temminck, Mammologie.

matous races; and amongst the ruminating, the giraffe, the Cape buffalo, and a variety of remarkable antelopes, as the springbok, the oryx, the gnou, the leucophoë, the pygarga, and several others.*

In the Indian archipelago.— The Indian archipelago presents peculiar phenomena in regard to its indigenous mammalia, which, in their generic character, recede, in some respects, from that of the animals of the Indian continent, and approximate to the African. The Sunda isles contain a hippopotamus, which is wanting in the rivers of Asia; Sumatra, a peculiar species of tapir, and a rhinoceros resembling the African more than the Indian species, but specifically distinguishable from both.†

Beyond the Indian archipelago is an extensive region, including New Guinea, New Britain, and New Ireland, together with the archipelago of Solomon's Islands, the New Hebrides, and Louisiade, and the more remote group of islands in the great southern ocean, which may be considered as forming one zoological province. Although these remarkable countries are extremely fertile in their vegetable productions, they are almost wholly destitute of native warm-blooded quadrupeds, except a few species of bats, and some domesticated animals in the possession of the natives.‡

Quadrupeds in islands. — Quadrupeds found on islands situated near the continents generally form a part of the stock of animals belonging to the adjacent mainland; " but small islands remote from continents

* Pennant's Hist. of Quadrupeds, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 66.

† Prichard, Phys. Hist. of Mankind, vol. i. p. 66.; Cuvier, Ann. du Muséum, tom. vii.

‡ Prichard, ibid., p. 56.

are in general altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by men. Kerguelen's Land, Juan Fernandez, the Gallapagos, and the Isles de Lobos, are examples of this fact. Among all the groups of fertile islands in the Pacific Ocean, no quadrupeds have been found, except dogs, hogs, rats, and a few bats. The bats have been found in New Zealand and the more westerly groups; they may probably have made their way along the chain of islands which extend from the shores of New Guinea far into the Southern Pacific. The hogs and the dogs appear to have been conveyed by the natives from New Guinea. The Indian islands, near New Guinea, abound in oxen, buffaloes, goats, deer, hogs, dogs, cats, and rats; but none of them are said to have reached New Guinea, except the hog and the dog. The New Guinea hog is of the Chinese variety, and was probably brought from some of the neighbouring islands, being the animal most in request among savages. It has run wild in New Guinea. Thence it has been conveyed to the New Hebrides, the Tonga and Society Isles, and to the Marquesas; but it is still wanting in the more easterly islands, and, to the southward, in New Caledonia.

"Dogs may be traced from New Guinea to the New Hebrides and Fiji Isles; but they are wanting in the Tonga Isles, though found among the Society and Sandwich islanders, by some of whom they are used for food: to the southward they have been conveyed to New Caledonia and New Zealand. In Easter Island, the most remotely situated in this ocean, there are no domestic animals except fowls and rats, which are eaten by the natives: these animals are found in most of the islands; the fowls are probably from New Guinea.

Rats are to be found even on some desert inlands, whither they may have been conveyed by canoes which have occasionally approached the shore. It is known, also, that rats occasionally swim in large numbers to considerable distances." *

Geographical range of the cetacea.—It is natural to suppose that the geographical range of the different species of cetacea should be less correctly ascertained than that of the terrestrial mammifers. It is, however, well known that the whales which are obtained by our fishers in the South Seas are distinct from those of the North; and the same dissimilarity has been found in all the other marine animals of the same class, so far as they have yet been studied by naturalists.

Dispersion of quadrupeds.—Let us now inquire what facilities the various land quadrupeds enjoy of spreading themselves over the surface of the earth. In the first place, as their numbers multiply, all of them, whether they feed on plants, or prey on other animals, are disposed to scatter themselves gradually over as wide an area as is accessible to them. But before they have extended their migrations over a large space, they are usually arrested either by the sea, or a zone of uncongenial climate, or some lofty and unbroken chain of mountains, or a tract already occupied by a hostile and more powerful species.

Their powers of swimming.—Rivers and narrow friths can seldom interfere with their progress; for the greater part of them swim well, and few are without this power when urged by danger and pressing want. Thus, amongst beasts of prey, the tiger is seen swimming about among the islands and creeks in the delta

* Prichard, Phys. Hist. of Mankind, vol. i. p. 75.

of the Ganges, and the jaguar traverses with ease the largest streams in South America.* The bear, also, and the bison, cross the current of the Mississippi. The popular error, that the common swine cannot escape by swimming when thrown into the water, has been contradicted by several curious and well-authenticated instances during the recent floods in Scotland. One pig, only six months old, after having been carried down from Garmouth to the bar at the mouth of the Spey, a distance of a quarter of a mile, swam four miles eastward to Port Gordon, and landed safe. Three others, of the same age and litter, swam, at the same time, five miles to the west, and landed at Blackhill.*

In an adult and wild state, these animals would doubtless have been more strong and active, and might, when hard pressed, have performed a much longer voyage. Hence islands remote from the continent may obtain inhabitants by casualities which, like the late storms in Morayshire, may only occur once in many centuries, or thousands of years, under all the same circumstances. It is obvious that powerful tides, winds, and currents, may sometimes carry along quadrupeds capable, in like manner, of preserving themselves for hours in the sea, to very considerable distances; and in this way, perhaps, the tapir (*Tapir Indicus*) may have become common to Sumatra and the Malayan peninsula.

To the elephant, in particular, the power of crossing rivers is essential in a wild state, for the quantity of food which a herd of these animals consumes renders it necessary that they should be constantly moving from place to place. The elephant crosses the stream

* Buffon, vol. v. p. 204.

† Sir T. D. Lauder, Bart., on the Floods in Morayshire, Aug. 1829, p. 302. second edition.

in two ways. If the bed of the river be hard, and the water not of too great a depth, he fords it. But when he crosses great rivers, such as the Ganges and the Niger, the elephant swims deep, so deep, that the end of his trunk only is out of the water; for it is a matter of indifference to him whether his body be completely immersed, provided he can bring the tip of his trunk to the surface, so as to breathe the external air.

Animals of the deer kind frequently take to the water, especially in the rutting season, when the stags are seen swimming for several leagues at a time, from island to island, in search of the does, especially in the Canadian lakes; and in some countries where there are islands near the sea shore, they fearlessly enter the sea and swim to them. In hunting excursions, in North America, the elk of that country is frequently pursued for great distances through the water.

The large herbivorous animals, which are gregarious, can never remain long in a confined region, as they consume so much vegetable food. The immense herds of bisons which often, in the great valley of the Mississippi, blacken the surface, near the banks of that river and its tributaries, are continually shifting their quarters, followed by wolves, which prowl about in their rear. "It is no exaggeration," says Mr. James, "to assert, that in one place, on the banks of the Platte, at least ten thousand bisons burst on our sight in an instant. In the morning, we again sought the living picture; but upon all the plain, which last evening was so teeming with noble animals, not one remained." *

* Expedition from Pittsburg to the Rocky Mountains, vol. ii. p. 153.

Migratory instincts. — Besides the disposition common to the individuals of every species slowly to extend their range in search of food, in proportion as their numbers augment, a migratory instinct often develops itself in an extraordinary manner, when, after an unusually prolific season, or upon a sudden scarcity of provisions, great multitudes are threatened by famine. It may be useful to enumerate some examples of these migrations, because they may put us upon our guard against attributing a high antiquity to a particular species merely because it is diffused over a great space: they show clearly how soon, in a state of nature, a newly created species might spread itself, in every direction, from a single point.

In very severe winters, great numbers of the black bears of America migrate from Canada into the United States; but in milder seasons, when they have been well fed, they remain and hybernate in the north.* The rein-deer which, in Scandinavia, can scarcely exist to the south of the sixty-fifth parallel, descends, in consequence of the greater coldness of the climate, to the fiftieth degree, in Chinese Tartary, and often roves into a country of more southern latitude than any part of England.

In Lapland, and other high latitudes, the common squirrels, whenever they are compelled, by want of provisions, to quit their usual abodes, migrate in amazing numbers, and travel directly forwards, allowing neither rocks and forests, nor the broadest waters, to turn them from their course. Great numbers are often drowned in attempting to pass friths and rivers. In like manner the small Norway rat sometimes pur-

* Richardson's Fauna Boreali-Americana, p. 16.

sues its migrations in a straight line across rivers and lakes; and Pennant informs us, that when the rats, in Kamtschatka, become too numerous, they gather together in the spring, and proceed in great bodies westward, swimming over rivers, lakes, and arms of the sea. Many are drowned or destroyed by water-fowl or fish. As soon as they have crossed the river Penginsk, at the head of the gulf of the same name, they turn southward, and reach the rivers Judoma and Okotsk by the middle of July; a district more than 800 miles distant from their point of departure.

The lemings, also, a small kind of rat, are described as natives of the mountains of Kolen, in Lapland; and once

Fig. 49.

The Leming, or Lapland Marmot (Mus Lemmus, *Linn.*).

or twice in a quarter of a century they appear in vast numbers, advancing along the ground, and "devouring every green thing." Innumerable bands march from the Kolen, through Nordland and Finmark, to the Western Ocean, which they immediately enter; and, after swimming about for some time, perish. Other bands take their route through Swedish Lapland, to the Bothnian Gulf, where they are drowned in the same manner. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly. They generally move in lines, which are about three feet from each other, and exactly parallel, going

directly forward through rivers and lakes; and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round.* These excursions usually precede a rigorous winter, of which the lemings seem in some way forewarned.

Vast troops of the wild ass, or *onager* of the ancients, which inhabit the mountainous deserts of Great Tartary, feed, during the summer, in the tracts east and north of Lake Aral. In the autumn they collect in herds of hundreds, and even thousands, and direct their course towards the north of India, and often to Persia, to enjoy a warm retreat during winter.† Bands of two or three hundred quaggas, a species of wild ass, are sometimes seen to migrate from the tropical plains of southern Africa to the vicinity of the Malaleveen river. During their migrations they are followed by lions, who slaughter them night by night.‡

The migratory swarms of the springbok, or Cape antelope, afford another illustration of the rapidity with which a species, under certain circumstances, may be diffused over a continent. When the stagnant pools of the immense deserts south of the Orange River dry up, which often happens after intervals of three or four years, myriads of these animals desert the parched soil, and pour down like a deluge on the cultivated regions near the Cape. The havoc committed by them resembles that of the African locusts; and so crowded are the herds, that "the lion has been seen to walk in the midst of the compressed phalanx with only as much room between him and his victims

* Phil. Trans., vol. ii. p. 872.

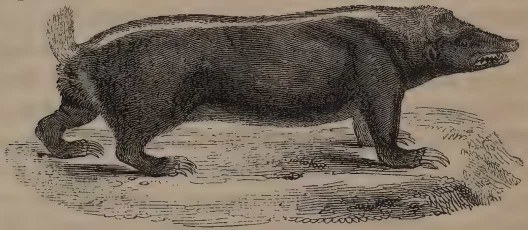
† Wood's Zoography, vol. i. p. 11.

‡ On the authority of Mr. Campbell. Library of Entert. Know., Menageries, vol. i. p. 152.

as the fears of those immediately around could procure by pressing outwards."*

Dr. Horsfield mentions a singular fact in regard to the geographical distribution of the Mydaus meliceps, an animal intermediate between the polecat and badger. It inhabits Java, and is "confined exclusively to those

Fig. 50.



Mydaus meliceps, or badger-headed Mydaus. Length, including the tail, 16 *inches.*

mountains which have an elevation of more than seven thousand feet above the level of the ocean; on these it occurs with the same regularity as many plants. The long-extended surface of Java, abounding with conical points which exceed this elevation, affords many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with this animal, which, from its peculiarities, is universally known to the inhabitants of these elevated tracts, while to those of the plains it is as strange as an animal from a foreign country. In my visits to the mountainous districts, I uniformly met with it; and, as far as the information of the natives can be relied on, it is found on all the mountains."†

* Cuvier's Animal Kingdom by Griffiths, vol. ii. p. 109. Library of Entert. Know., Menageries, vol. i. p. 366.

† Horsfield, Zoological Researches in Java, No. ii., from which the figure is taken.

Now, if asked to conjecture how the Mydaus arrived at the elevated regions of each of these isolated mountains, we might say that, before the island was peopled by man, by whom their numbers are now thinned, they may occasionally have multiplied so as to be forced to collect together and migrate: in which case, notwithstanding the slowness of their motions, some few would succeed in reaching another mountain, some twenty, or even, perhaps, fifty miles distant; for although the climate of the hot intervening plains would be unfavourable to them, they might support it for a time, and would find there abundance of insects on which they feed. Volcanic eruptions, which, at different times, have covered the summits of some of those lofty cones with sterile sand and ashes, may have occasionally contributed to force on these migrations.

Drifting of animals on ice-floes.—The power of the terrestrial mammalia to cross the sea is very limited, and it was before stated that the same species is scarcely ever common to districts widely separated by the ocean. If there be some exceptions to this rule, they generally admit of explanation; for there are natural means whereby some animals may be floated across the water, and the sea sometimes wears a passage through a neck of land, leaving individuals of a species on each side of the new channel. Polar bears are known to have been frequently drifted on the ice from Greenland to Iceland: they can also swim to considerable distances, for Captain Parry, on the return of his ships through Barrow's Strait, met with a bear swimming in the water about midway between the shores, which were about forty miles apart, and

where no ice was in sight.* "Near the east coast of Greenland," observes Scoresby, "they have been seen on the ice in such quantities, that they were compared to flocks of sheep on a common; and they are often found on field-ice, above two hundred miles from the shore."† Wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young seals, which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea; and though some may be drifted to islands or continents, the greater part of them perish, and have been often heard in this situation howling dreadfully, as they die by famine.‡

During the short summer which visits Melville Island, various plants push forth their leaves and flowers the moment the snow is off the ground, and form a carpet spangled with the most lively colours. These secluded spots are reached annually by herds of musk-oxen and rein-deer, which travel immense distances over dreary and desolate regions, to graze undisturbed on these luxuriant pastures. § The rein-deer often pass along in the same manner, by the chain of the Aleutian Islands, from Behring's Straits to Kamtschatka, subsisting on the moss found in these islands during their passage. ||

On floating islands of drift-wood.—Within the tropics there are no ice-floes; but, as if to compensate for that mode of transportation, there are floating islets of matted trees, which are often borne along

* Append. to Parry's Second Voyage, years 1819–20.

† Account of the Arctic Regions, vol. i. p. 518.

‡ Turton, in a note to Goldsmith's Nat. Hist., vol. iii. p. 43.

§ Supplement to Parry's First Voyage of Disc., p. 189.

|| Godman's American Nat. Hist., vol. i. p. 22.

through considerable spaces. These are sometimes seen sailing at the distance of fifty or one hundred miles from the mouth of the Ganges, with living trees standing erect upon them. The Amazon, the Congo, and the Orinoco, also produce these verdant rafts, which are formed in the manner already described when speaking of the great raft of the Atchafalaya, an arm of the Mississippi, where a natural bridge of timber, ten miles long, and more than two hundred yards wide, has existed for more than forty years, supporting a luxuriant vegetation, and rising and sinking with the water which flows beneath it.* That this enormous mass will one day break up and send down a multitude of floating islands to the Gulf of Mexico, is the hope and well-founded expectation of the inhabitants of Louisiana.

On these green islets of the Mississippi, observes Malte-Brun, young trees take root, and the pistia and nenuphar display their yellow flowers: there serpents, birds, and the cayman alligator, come to repose, and all are sometimes carried to the sea, and engulphed in its waters.†

Spix and Martius relate that, during their travels in Brazil, they were exposed to great danger while ascending the Amazon in a canoe, from the vast quantity of drift-wood constantly propelled against them by the current; so much so, that their safety depended on the crew being always on the alert to turn aside the trunks of trees with long poles. The tops alone of some trees appeared above water, others had their roots attached to them with so much soil that they

* See vol. I. p. 282.

† System of Geography, vol. v. p. 157.

might be compared to floating islets. On these, say the travellers, we saw some very singular assemblages of animals, pursuing peacefully their uncertain way in strange companionship. On one raft were several grave-looking storks, perched by the side of a party of monkeys, who made comical gestures, and burst into loud cries, on seeing the canoe. On another was seen a number of ducks and divers, sitting by a group of squirrels. Next came down, upon the stem of a large rotten cedar-tree, an enormous crocodile, by the side of a tiger-cat, both animals regarding each other with hostility and mistrust, but the saurian being evidently most at his ease, as conscious of his superior strength.*

In a memoir lately published, a naval officer informs us, that, as he returned from China by the eastern passage, he fell in, among the Moluccas, with several small floating islands of this kind, covered with mangrove-trees interwoven with underwood. The trees and shrubs retained their verdure, receiving nourishment from a stratum of soil which formed a white beach round the margin of each raft, where it was exposed to the washing of the waves and the rays of the sun.† The occurrence of soil in such situations may easily be explained; for all the natural bridges of timber which occasionally connect the islands of the Ganges, Mississippi, and other rivers, with their banks, are exposed to floods of water, densely charged with sediment.

Captain W. H. Smyth informs me, that, when cruizing in the Cornwallis amidst the Philippine Islands, he

* Spix and Martius, Reise, &c., vol. iii. pp. 1011. 1013.

† United Service Journal, No. xxiv. p. 697.

has more than once seen, after those dreadful hurricanes called typhoons, floating masses of wood, with trees growing upon them; and ships have sometimes been in imminent peril, as often as these islands were mistaken for terra firma, when, in fact, they were in rapid motion.

It is highly interesting to trace, in imagination, the effects of the passage of these rafts from the mouth of a large river to some archipelago, such as those in the South Pacific, raised from the deep, in comparatively modern times, by the operations of the volcano and the earthquake, and the joint labours of coral animals and testacea. If a storm arise, and the frail vessel be wrecked, still many a bird and insect may succeed in gaining, by flight, some island of the newly formed group, while the seeds and berries of herbs and shrubs, which fall into the waves, may be thrown upon the strand. But if the surface of the deep be calm, and the rafts are carried along by a current, or wafted by some slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark, and thus a colony of several hundred new species may at once be naturalized.

The reader should be reminded, that I merely advert to the transportation of these rafts as of extremely rare and accidental occurrence; but it may account, in tropical countries, for some of the rare exceptions to the general law of the confined range of species.

Migrations of the cetacea.—Many of the cetacea, the whales of the northern seas for example, are found to desert one tract of the sea, and to visit another

very distant, when they are urged by want of food or danger. The seals also retire from the coasts of Greenland in July, return again in September, and depart again in March, to return in June. They proceed in great droves northwards, directing their course where the sea is most free from ice, and are observed to be extremely fat when they set out on this expedition, and very lean when they come home again.*

Species of the Mediterranean, Black Sea, and Caspian, identical.—Some naturalists have wondered that the sea calves, dolphins, and other marine mammalia of the Mediterranean and Black Sea, should be identical with those found in the Caspian; and among other fanciful theories, they have suggested that they may dive through subterranean conduits, and thus pass from one sea into the other. But as the occurrence of wolves and other noxious animals, on both sides of the British Channel, was adduced, by Desmarest, as one of many arguments to prove that England and France were once united; so the correspondence of the aquatic species of the inland seas of Asia with those of the Black Sea tends to confirm the hypothesis, for which there are abundance of independent geological data, that those seas were connected together by straits at no remote period of the earth's history.

Geographical Distribution and Migrations of Birds.

I shall now offer a few observations on some of the other divisions of the animal kingdom. Birds, not-

* Krantz, vol. i. p. 129., cited by Goldsmith, Nat. Hist., vol. iii. p. 260.

withstanding their great locomotive powers, form no exception to the general rules already laid down; but, in this class, as in plants and terrestrial quadrupeds, different groups of species are circumscribed within definite limits. We find, for example, one assemblage in the Brazils, another in the same latitudes in Central Africa, another in India, and a fourth in New Holland. But some species, again, are so local, that in the same archipelago, a single island frequently contains a species found in no other spot on the whole earth; as is exemplified in some of the parrot tribes. In this extensive family, which are, with few exceptions, inhabitants, of tropical regions, the American group has not one in common with the African, nor either of these with the parrots of India.*

Another illustration is afforded by that minute and beautiful tribe, the humming birds. The whole of them are, in the first place, peculiar to the new world; but there, although some have a considerable range, as the *Trochilus flammifrons*, which is common to Lima, the island of Juan Fernandez, and the Straits of Magellan †; other species are peculiar to some of the West India islands, and have not been found elsewhere in the western hemisphere. The ornithology of our own country affords a no less striking exemplification of the same law; for the common grouse (*Tetrao scoticus*) occurs nowhere in the known world except in the British isles.

Some species of the vulture tribe are said to be

* Prichard, vol. i. p. 47.

† Captain King, during his late survey, found this bird at the Straits of Magellan, in the month of May—the depth of winter—sucking the flowers of the large species of fuchsia, then in bloom, in the midst of a shower of snow.

true cosmopolites; and the common wild goose (*Anas anser*, Linn.), if we may believe some ornithologists, is a general inhabitant of the globe, being met with from Lapland to the Cape of Good Hope, frequent in Arabia, Persia, China, and Japan, and in the American continent, from Hudson's Bay to South Carolina.* An extraordinary range has also been attributed to the nightingale, which extends from western Europe to Persia, and still farther. In a work entitled Specchio Comparativo †, by Charles Bonaparte, many species of birds are enumerated as common to Rome and Philadelphia; the greater part of these are migratory, but some of them, such as the long-eared owl (*Strix otus*), are permanent in both countries.

Their facilities of diffusion.—In parallel zones of the northern and southern hemispheres, a great general correspondence of form is observable, both in the aquatic and terrestrial birds; but there is rarely any specific identity: and this phenomenon is truly remarkable, when we recollect the readiness with which some birds, not gifted with great powers of flight, shift their quarters to different regions, and the facility with which others, possessing great strength of wing, perform their aërial voyage. Some migrate periodically from high latitudes, to avoid the cold of winter, and the accompaniments of cold,—scarcity of insects and vegetable food; others, it is said, for some particular kinds of nutriment required for rearing their young: for this purpose, they often traverse the ocean for thousands of miles, and recross it at other periods, with equal security.

* Bewick's Birds, vol. ii. p. 294., who cites Latham.

† Pisa, 1827 (not sold).

Periodical migrations, no less regular, are mentioned by Humboldt, of many American water-fowl, from one part of the tropics to another in a zone where there is the same temperature throughout the year. Immense flights of ducks leave the valley of the Orinoco, when the increasing depth of its waters and the flooding of its shores prevent them from catching fish, insects, and aquatic worms. They then betake themselves to the Rio Negro and Amazon, having passed from the eighth and third degrees of north latitude to the first and fourth of south latitude, directing their course south-south-east. In September, when the Orinoco decreases and re-enters into its channel, these birds return northwards.*

The insectivorous swallows which visit our island would perish during winter, if they did not annually repair to warmer climes. It is supposed that, in these aërial excursions the average rapidity of their flight is not less than fifty miles an hour; so that, when aided by the wind, they soon reach warmer latitudes. Spallanzani calculated that the swallow can fly at the rate of ninety-two miles an hour, and conceived that the rapidity of the swift might be three times greater.† The rate of flight of the eider duck (*Anas mollissima*) has been ascertained to be ninety miles an hour; and that of hawks, and several other tribes, to be 150 miles.

When we reflect how easily different species, in a great lapse of ages, may be each overtaken by gales and hurricanes, and, abandoning themselves to the tempest, be scattered at random through various regions of the earth's surface, where the temperature

* Voyage aux Régions Equinoxiales, tome vii. p. 429.

† Fleming, Phil. Zool., vol. ii. p. 43.

of the atmosphere, the vegetation, and the animal productions, might be suited to their wants, we shall be prepared to find some species capriciously distributed, and to be sometimes unable to determine the native countries of each. Captain Smyth informs me, that, when engaged in his survey of the Mediterranean, he encountered a gale in the Gulf of Lyons, at the distance of between twenty and thirty leagues from the coast of France, which bore along many land birds of various species, some of which alighted on the ship, while others were thrown with violence against the sails. In this manner islands become tenanted by species of birds inhabiting the nearest mainland.

Geographical Distribution and Dissemination of Reptiles.

A few facts respecting the third great class of vertebrated animals will suffice to show that the plan of nature in regard to their location on the globe is perfectly analogous to that already exemplified in other parts of the organic creation, and has probably been determined by similar causes.

Habitations of reptiles. — Of the great saurians, the gavials which inhabit the Ganges differ from the cayman of America, or the crocodile of the Nile. The monitor of New Holland is specifically distinct from the Indian species; these latter, again, from the African, and all from their congeners in the new world. So in regard to snakes; we find the boa of America represented by the python, a different though nearly allied genus in India. America is the country of the rattlesnake; Africa, of the cerastes; and Asia, of the hooded snake, or cobra di capello.

There is a legend that St. Patrick expelled all rep-

tiles from Ireland; and certain it is that none of the three species of snakes common in England, nor the toad, have been observed there by naturalists. They have our common frog, and our water-newt, and according to Ray (Quad. 264.), the green lizard (*Lacerta viridis*). Schultes the botanist observed, a few years since, in his tour in England, that there were two great islands in Europe of which the floras were unknown — Sardinia and Ireland; he might perhaps, have added, the fauna of the latter country.

Migrations of the larger reptiles. — The range of the large reptiles is, in general, quite as limited as that of some orders of the terrestrial mammalia. The great saurians sometimes cross a considerable tract in order to pass from one river to another; but their motions by land are generally slower than those of quadrupeds. By water, however, they may transport themselves to distant situations more easily. The larger alligator of the Ganges sometimes descends beyond the brackish water of the Delta into the sea; and in such cases it might chance to be drifted away by a current, and survive till it reached a shore at some distance; but such casualities are probably very rare.*

Turtles migrate in large droves from one part of the ocean to another during the ovipositing season. Dr. Fleming, mentions, that an individual of the hawk's bill turtle (*Chelonia imbricata*), so common in the American seas, has been taken at Papa Stour, one of the West Zetland islands†; and, according to Sibbald, "the

* Malte-Brun says (Syst. of Geog., vol. viii. p. 193.), that a crocodile is still preserved at Lyons that was taken from the *Rhone*, about two centuries ago; but no particulars are given.

† Brit. Animals, p. 149.; who cites Sibbald.

same animal came into Orkney." Another was taken, in 1774, in the Severn, according to Turton. Two instances, also, of the occurrence of the leathern tortoise (*C. coriacea*), on the coast of Cornwall, in 1756, are mentioned by Borlase. These animals of more southern seas can be considered only as stragglers attracted to our shores during uncommonly warm seasons by an abundant supply of food, or carried by the Gulf stream, or driven by storms to high latitudes.

Some of the smaller reptiles lay their eggs on aquatic plants; and these must often be borne rapidly by rivers, and conveyed to distant regions in a manner similar to the dispersion of seeds before adverted to. But that the larger ophidians may be themselves transported across the seas, is evident from the following most interesting account of the arrival of one at the island of St. Vincent. It is worthy of being recorded, says Mr. Guilding, "that a noble specimen of the *Boa constrictor* was lately conveyed to us by the currents, twisted round the trunk of a large sound cedar tree, which had probably been washed out of the bank by the floods of some great South American river, while its huge folds hung on the branches, as it waited for its prey. The monster was fortunately destroyed after killing a few sheep, and his skeleton now hangs before me in my study, putting me in mind how much reason I might have had to fear in my future rambles through the forests of St. Vincent, had this formidable reptile been a pregnant female, and escaped to a safe retreat."*

* Zool. Journ., vol. iii. p. 406. Dec. 1827.

CHAPTER VII.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES—*continued.*

Geographical distribution and migrations of fish — of testacea — of zoophytes (p. 82.) — Distribution of insects — Migratory instincts of some species — Certain types characterize particular countries — Their means of dissemination — Geographical distribution and diffusion of man (p. 89.) — Speculations as to the birth-place of the human species — Progress of human population — Drifting of canoes to vast distances — On the involuntary influence of man in extending the range of many other species (p. 95.).

Geographical Distribution and Migrations of Fish.

Although we are less acquainted with the habitations of marine animals than with the grouping of the terrestrial species before described, yet it is well ascertained that their distribution is governed by the same general laws. The testimony borne by MM. Péron and Lesueur to this important fact is remarkably strong. These eminent naturalists, after collecting and describing many thousand species of marine animals which they brought to Europe from the southern hemisphere, insist most emphatically on their distinctness from those north of the equator; and this remark they extend to animals of all classes, from those of a more simple to those of a more complex organization — from the sponges and medusæ to the cetacea. "Among all those which we have been able to examine," say

they, "with our own eyes, or with regard to which it has appeared to us possible to pronounce with certainty, there is not a single animal of the southern regions which is not distinguished by essential characters from the analogous species in the northern seas."*

The fish of the Arabian Gulf are said to differ entirely from those of the Mediterranean, notwithstanding the proximity of these seas. The flying-fish are found (some stragglers excepted) only between the tropics; in receding from the line, they never approach a higher latitude than the fortieth parallel. Those inhabiting the Atlantic are said to be different species from those of the eastern ocean.† The electric gymnotus belongs exclusively to America; the trembler, or *Silurus electricus*, to the rivers of Africa; but the torpedo, or cramp-fish, is said to be dispersed over all tropical, and many temperate seas.‡

All are aware that there are certain fish of passage which have their periodical migrations, like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The herring and the haddock, after frequenting certain shores, in vast shoals, for a series of years, desert them again, and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the

* Sur les Habitations des Animaux Marins.—Ann. du Mus., tom. xv., cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 51.

† Malte-Brun, vol. i. p. 507.

‡ Ibid.

course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it.* Before the year 1800 there were no eels in Lake Wener, the largest inland lake in Sweden, which discharges its waters by the celebrated cataracts of Trolhättan. But I am informed by Professor Nilsson that since the canal was opened uniting the river Gotha with the lake by a series of nine locks, each of great height, eels have been observed in abundance in the lake. It appears, therefore, that though they were unable to ascend the falls, they have made their way by the locks, by which in a very short space a difference of level of 114 feet is overcome.

Gmelin says, that the anseres (wild geese, ducks, and others) subsist, in their migrations, on the spawn of fish; and that oftentimes, when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired.† When there are many disconnected freshwater lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source; but it has been suggested, that the minute eggs of these animals may sometimes be entangled in the feathers of water-fowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water-beetles, also, as the dyticidæ, are amphibious, and in the evening quit their lakes and pools, and, flying in the air, transport the minute ova of fishes to distant waters.

* Phil. Trans., 1747, p. 395.

† Amœn. Acad., Essay 75.

In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains.

Geographical Distribution and Migrations of Testacea.

The testacea, of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist; because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine molluscs is extensive.

Causes which limit the extension of many species. — Some forms, as those of the nautili, volutæ, and cyprææ, attain their fullest development in warm latitudes; and most of their species are exclusively confined to them. Péron and Lesueur remark, that the Haliotis gigantea of Van Diemen's Land, and the Phasianella, diminish in size as they follow the coasts of New Holland to King George's Sound, and entirely disappear beyond them.* Almost all the species of South American shells differ from those of the Indian Archipelago in the same latitudes; and on the shores of many of the islands of the South Pacific, peculiar species have been obtained. But we are as yet by no means able to sketch out the submarine provinces of shells, as the botanist has done those of the terrestrial, and even of the subaqueous plants. There can be

* Ann. du Mus. d'Hist. Nat., tom. xv.

little doubt, however, that the boundaries in this case, both of latitude and longitude, will be found in general well defined. The continuous lines of continents, stretching from north to south, prevent a particular species from belting the globe, and following the direction of the isothermal lines. The inhabitants of the West Indian seas, for example, cannot enter the Pacific, without passing round through the inclement climate of Cape Horn. Currents also flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses.

Great range of some species. — Some few species, however, have an immense range, as the *Bulla aperta*, for example, which is found in almost all zones. The habitation of the *Bulla striata* extends from the shores of Egypt to the coasts of England and France, and it recurs again in the seas of Senegal, Brazil, and the West Indies. The *Turbo petræus* inhabits the seas of England, Guadaloupe, and the Cape of Good Hope *, and many instances of a similar kind might be enumerated.

The *Ianthina fragilis* has wandered into almost every sea, both tropical and temperate. This "common oceanic snail" derives its buoyancy from an admirably contrived float, which has enabled it not only to disperse itself so universally, but to become an active agent in disseminating other species, which attach themselves, or their ova, to its shell.†

* Fér. Art. Géogr. Phys. Dict. Class. d'Hist. Nat.

† Mr. Broderip possesses specimens of *Ianthina fragilis*, bearing more than one species of barnacle (*Pentelasmis*) presented to

It is evident that, among the testacea, as in plants and the higher order of animals, there are species which have a power of enduring a wide range of temperature, whereas others cannot resist a considerable change of climate. Among the freshwater molluscs, and those which breathe air, Férussac mentions a few instances of species of almost universal diffusion.

The Helix putris (*Succinea putris*,* Lam.), so common in Europe, where it reaches from Norway to Italy, is also found in Egypt, in the United States, in Newfoundland, Jamaica, Tranquebar, and, it is even said, in the Marianne Isles. As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different water-fowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. *Helix aspersa*, one of the commonest of our larger land-shells, is found in South America, at the foot of Chimborazo, as also in Cayenne. Some conchologists have conjectured that it was accidentally imported in some ship; for it is an eatable species, and these animals are capable of retaining life during long voyages, without air or nourishment.*

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him by Captain King and Lieutenant Graves. One of these specimens, taken alive by Captain King far at sea, and a little north of the equator, is so loaded with those cirrhipeds, and with numerous ova, that all the upper part of its shell is invisible.

* Four individuals of a large species of land shell (*Bulimus*), from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his late expedition to the Straits of Magellan. They had been packed up in a box, and enveloped in cotton; two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months; but, on being exposed by Mr. Broderip to the warmth of a fire in London, and

Confined range of others. — Mr. Lowe, in a memoir published in the Cambridge Transactions in 1831, enumerates seventy-one species of land mollusca, collected by him in the islands of Madeira and Porto Santo, sixty of which belonged to the genus Helix alone, including as sub-genera Bulimus and Achatina, and excluding Vitrina and Clausilia; — forty-four of these are new. It is remarkable, that very few of the above-mentioned species are common to the neighbouring archipelago of the Canaries; but it is a still more striking fact, that, of the sixty species of the three genera above mentioned, thirty-one are natives of Porto Santo; whereas, in Madeira, which contains ten times the superficies, were found but twenty-nine. Of these only four were common to the two islands, which are separated by a distance of only twelve leagues; and two even of these four (namely, *Helix rhodostoma* and *H. ventrosa*) are species of general diffusion, common to Madeira, the Canaries, and the South of Europe.*

The confined range of these molluscs may easily be explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions — to account for the dissemination of some species throughout several islands, and the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

Their mode of diffusion. — Notwithstanding the proverbially slow motion of snails and molluscs in

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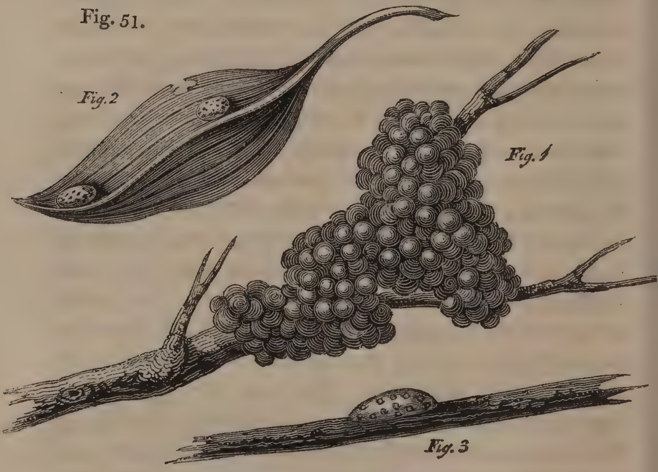
provided with tepid water and leaves, they revived, and lived for several months in Mr. Loddiges' palm-house.

* Camb. Phil. Trans., vol. iv., 1831.

general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth; and this buoyant substance floats far and wide as readily as sea-weed. The young of other viviparous tribes are often borne along, entangled in sea-weed. Sometimes they are so light, that, like grains of sand, they can be easily moved by currents. Balani and serpulæ are

Fig. 51.



Eggs of fresh-water Molluscs.

Fig. 1. Eggs of Ampullaria ovata (a fluviatile species), fixed to a small sprig which had fallen into the water.

Fig. 2. Eggs of Planorbis albus, attached to a dead leaf lying under water.

Fig. 3. Eggs of the common Limneus (L. vulgaris), adhering to a dead stick under water.

sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice. In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away during floods, from tributaries to the main streams, and from thence to all parts of the same basins. Particular species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles.

An illustration of the mode of attachment of these eggs will be seen in the annexed cut. (Fig. 51.)

The habit of some testacea to adhere to floating wood is proved by their fixing themselves to the bottoms of ships. By this mode of conveyance *Mytilus polymorphus* has been brought from northern Europe to the Commercial Docks in the Thames, where the species is now domiciled.

A lobster (*Astacus marinus*) was lately taken alive covered with living mussels (*Mytilus edulis*)*; and a large female crab (*Cancer pagurus*), covered with oysters, and bearing also Anomia ephippium, and actiniæ, was taken in April, 1832, off the English coast. The oysters, seven in number, include individuals of six years' growth, and the two largest are four inches long and three inches and a half broad. Both the crab and the oysters were seen alive by Mr. Robert Brown.†

* The specimen is preserved in the Museum of the Zool. Soc. of London.

† This specimen is in the collection of my friend Mr. Broderip, who observes, that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists

From this example we learn the manner in which oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on the death of the crab. In this instance the oysters survived the crab many days, and were killed at last only by long exposure to the air.

Geographical Distribution and Migrations of Zoophytes.

Zoophytes are very imperfectly known, but there can be little doubt that each maritime region possesses species peculiar to itself. The madrepores, or lamelliferous polyparia, are found in their fullest development only in the tropical seas of Polynesia and the East and West Indies; and this family is represented only by a few species in our seas. Those even of the Mediterranean are inferior in size; and, for the most part, different from such as inhabit the tropics. Péron and Lesueur, after studying the Holothuriæ, Medusæ, and other congeners of delicate and changeable forms, came to the conclusion that each kind has its place of residence determined by the temperature necessary to support its existence. Thus, for example, they found the abode of Pyrosoma Atlantica to be confined to one particular region of the Atlantic Ocean.*

Let us now inquire how the transportation of polyps from one part of the globe to another is effected.

have stated that the species moults annually, without limiting the moulting period to the early stages of growth of the animal.

* Voy. aux Terres Australes, tome i. p. 492.

Many of them, as in the families Flustra and Sertularia, attach themselves to sea-weed, and are occasionally drifted along with it. Many fix themselves to the shells of gasteropods, and are thus borne along by them to short distances. Some polyps, like the sea-pens, float about in the sea, although naturalists are not agreed whether or not they possess powers of spontaneous motion. But the most frequent mode of transportation consists in the buoyancy of their eggs, or certain small vesicles, which are detached, and are capable of becoming the foundation of a new colony. These gems, as they are called, have in many instances a locomotive power of their own, by which they proceed in a determinate direction for several days after separation from the parent. They are propelled by means of numerous short threads or hairs, which are in constant and rapid vibration; and, when thus supported in the water, they may be borne along by currents to a great distance.

That some zoophytes adhere to floating bodies, is proved by their being found attached to the bottoms of ships, like certain testacea before alluded to.

Geographical Distribution and Migrations of Insects.

Before I conclude this sketch of the manner in which the habitable parts of the earth are shared out among particular assemblages of organic beings, I must offer a few remarks on insects, which, by their numbers and the variety of their powers and instincts, exert a prodigious influence in the economy of animate nature. As a large portion of these minute creatures are strictly dependent for their subsistence on certain species of vegetables, the entomological provinces must coincide in a considerable degree with the botanical.

All the insects, says Latreille, brought from the eastern parts of Asia and China, whatever be their latitude and temperature, are distinct from those of Europe and of Africa. The insects of the United States, although often they approach very close to our own, are nevertheless specifically distinguishable by some characters. In South America, the equinoctial lands of New Granada and Peru on the one side, and of Guiana on the other, contain for the most part distinct groups; the Andes forming the division, and interposing a narrow line of severe cold between climates otherwise very similar.*

Migratory instincts. — The insects of the United States, even those of the northern provinces as far as Canada, differ specifically from the European; while those of Greenland appear to be in a great measure identical with our own. Some insects are very local; while a few, on the contrary, are common to remote countries, between which the torrid zone and the ocean intervene. Thus our painted lady butterfly (*Vanessa cardui*) re-appears in New Holland and Japan with scarcely a varying streak.† The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, and America; and its wide range is the more interesting, because it seems explained by its migratory instinct, seconded, no doubt, by a capacity, enjoyed by few species, of enduring a great diversity of temperature.

A vast swarm of this species, forming a column from

* Géographie Générale des Insectes et des Arachnides. Mém. du Mus. d'Hist. Nat., tome iii.

† Kirby and Spence, vol. iv. p. 487.

ten to fifteen feet broad, was, a few years since, observed in the Canton de Vaud; they traversed the country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin. The fact is the more worthy of notice, because the caterpillars of this butterfly are not gregarious, but solitary from the moment that they are hatched; and this instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Not only peculiar species, but certain types, distinguish particular countries; and there are groups, observes Kirby, which represent each other in distant regions, whether in their form, their functions, or in both. Thus the honey and wax of Europe, Asia, and Africa, are in each case prepared by bees congenerous with our common hive-bee (*Apis*, Latr.); while, in America, this genus is nowhere indigenous, but is replaced by Melipona, Trigona, and Euglossa; and in New Holland by a still different, but undescribed type.* The European bee (*Apis mellifica*), although not a native of the new world, is now established, both in

* Kirby and Spence, vol. iv. p. 497.

North and South America. It was introduced into the United States by some of the early settlers, and has since overspread the vast forests of the interior, building hives in the decayed trunks of trees. "The Indians," says Irving, "consider them as the harbinger of the white man as the buffalo is of the red man, and say that in proportion as the bee advances the Indian and the buffalo retire. It is said," continues the same writer, "that the wild bee is seldom to be met with at any great distance from the frontier, and that they have always been the heralds of civilization, preceding it as it advanced from the Atlantic borders. Some of the ancient settlers of the west even pretend to give the very year when the honey-bee first crossed the Mississippi."*

As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as I before stated, when speaking of floating seeds, may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air.†

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they

* Washington Irving's Tour in the Prairies, ch. ix.

† Description of the Equatorial Regions — Malte-Brun, vol. v. p. 379.

alighted at Selbourne, spreading at the same time in great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella septempunctata*), which feed upon them.*

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the libellulæ, coccinellæ, carabi, cicadæ, &c. are not usually social insects; but seem to congregate, like swallows, merely for the purpose of emigration.† Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious, and to venture sometimes even to cross the ocean.

The armies of locusts which darken the air in Africa and traverse the globe from Turkey to our southern counties in England, are well known to all. When the western gales sweep over the Pampas, they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused, I may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint.‡ Captain W. H. Smyth was obliged to repaint his vessel, the Adventure, in

* Kirby and Spence, vol. ii. p. 9. 1817. † Ibid. p. 12.

‡ I am indebted to Lieutenant Graves, R.N., for this information.

the Mediterranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

To the southward of the river Plate, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's late expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned; for many can repose without sinking on the water. The slender long-legged tipulæ have been seen standing on the surface of the sea, when driven out far from our coast, and took wing immediately on being approached.* Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt water; and the periodical appearance of some conspicuous butterflies amongst us, after being unseen for five or fifty years, has been ascribed, not without probability, to the agency of the winds.

Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c.; so that when the waters subside, the entomologist may generally reap a plentiful harvest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in num-

* I state this fact on the authority of my friend, Mr. John Curtis.

berless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable, like seeds, of resisting the digestive powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

Geographical Distribution and Diffusion of Man.

I have reserved for the last some observations on the range and diffusion of the human species over the earth, and the influence of man in spreading other animals and plants, especially the terrestrial.

Many naturalists have amused themselves in speculating on the probable birth-place of mankind, the point from which, if we assume the whole human race to have descended from a single pair, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birth-place was situated within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

Progress of human population.—"The hunter state," it has been argued, "which Montesquieu placed the first, was probably only the second stage to which mankind arrived; since so many arts must have been invented to catch a salmon, or a deer, that society could no longer have been in its infancy when they came into use."* When regions where the spontaneous fruits of

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate zone; but a considerable time would probably elapse before this event took place; and it is possible, as a writer before cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practised at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity.*

A distinguished modern writer, who coincides for the most part in the views above mentioned, has introduced one of the persons in his second dialogue as objecting to the theory of the human race having gradually advanced from a savage to a civilized state, on the ground that "the first man must have inevitably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force."† He then contends against the difficulty here started by various arguments, all of which were, perhaps, superfluous; for if a philosopher is pleased to indulge in conjectures on this subject, why should he not assign, as the original seat of man, some one of those large islands within the tropics, which are as free from wild beasts as Van Diemen's Land or Australia? Here man may have remained for a period, peculiar to a single island, just as some of the large anthropomor-

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

† Sir H. Davy, Consolations in Travel, p. 74.

phous species are now limited to one island within the tropics. In such a situation, the new-born race might have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country, until the whole is covered with scattered settlements. It has been calculated that eight hundred acres of hunting-ground produce only as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost invariably been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally by seals and turtles, and was covered with a forest of trees and shrubs, all of species peculiar to it, with one or

two exceptions, and which seem to have been expressly created for this remote and insulated spot.*

Drifting of canoes to vast distances. — But very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to inquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Cook, Forster, and others, have remarked that parties of savages in their canoes must often have lost their way, and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Captain Cook found on the island of Wateoo three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is 550 miles. In 1696, two canoes, containing thirty persons, who had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of 800 miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Farroilep to the island of Guaham, one of the Marians, a distance of 200 miles.†

Kotzebue, when investigating the Coral Isles of Radack, at the eastern extremity of the Caroline Isles, became acquainted with a person of the name of Kadu, who was a native of Ulea, an isle 1500 miles distant, from which he had been drifted with a

* See Vol. III. p. 28.

† Malte-Brun's Geography, vol. iii. p. 419.

party. Kadu and three of his countrymen one day left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course; they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. "Kadu," says Kotzebue, "who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening."* When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur, in a state of insensibility; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.†

Captain Beechey, in his late voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked, to the number of 150 souls, in three double canoes, from Anaa, or Chain Island, situated about three hundred miles to the eastward of Otaheite. They were overtaken by the monsoon, which dispersed the canoes;

* Chamisso states that the water which they brought up was cooler, and, *in their opinion*, less salt. It is difficult to conceive its being fresher near the bottom, except where submarine springs may happen to rise.

† Kotzebue's Voyage, 1815—1818. Quarterly Review, vol. xxvi. p. 361.

and, after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of, but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of 600 miles, they were found and carried to their home in the Blossom.*

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America: so that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then, to wonder, that during the ages required for some tribes of the human race to attain that advanced stage of civilization which empowers the navigator to cross the ocean in all directions with security, the whole earth should have become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we might expect their descendants, though they should never become more enlightened than the South Sea Islanders or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase, in a

* Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

limited district, beyond the means of subsistence, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Involuntary Influence of Man in diffusing Animals and Plants.

Many of the general remarks which have been made respecting the influence of man in spreading or in checking the diffusion of plants, apply equally to his relations with the animal kingdom. On a future occasion, I shall be led to speak of the instrumentality of our species in naturalizing useful animals and plants in new regions, when explaining my views of the effects which the spreading and increase of certain species exert in the extirpation of others. At present I shall confine myself to a few remarks on the involuntary aid which man lends to the dissemination of species.

In the mammiferous class our influence is chiefly displayed in increasing the number of quadrupeds which are serviceable to us, and in exterminating or reducing the number of those which are noxious.

Sometimes, however, we unintentionally promote the multiplication of inimical species, as when we introduced the rat, which was not indigenous in the new world, into all parts of America. They have been conveyed over in ships, and now infest a great multitude of islands and parts of that continent. In like manner the Norway rat has been imported into England, where it plunders our property in ships and houses.

Among birds, the house sparrow may be cited as a species known to have extended its range with the tillage of the soil. During the last century it has

spread gradually over Asiatic Russia towards the north and east, always following the progress of cultivation. It made its first appearance on the Irtisch in Tobolsk, soon after the Russians had ploughed the land. It came in 1735 up the Obi to Beresow, and four years after to Naryn, about fifteen degrees of longitude farther east. In 1710, it had been seen in the higher parts of the course of the Lena, in the government of Irkutzk. In all these places it is now common, but is not yet found in the uncultivated regions of Kamtschatka.*

The great viper (*Fer de lance*), a species no less venomous than the rattle-snake, which now ravages Martinique and St. Lucia, was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to an *universal* geographical distribution.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. Notwithstanding the coldness of our climate, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North American

* Gloger, Abänd. der Vögel, p. 103.; Pallas, Zoog. Rosso-Asiat., tom. ii. p. 197.

species. "The commercial relations," says Malte-Brun*, "between France and India, have transported from the latter country the aphis which destroys the apple-tree, and two sorts of Neuroptera, the *lucifuga* and *flavicola*, mostly confined to Provence and the neighbourhood of Bourdeaux, where they devour the timber in the houses and naval arsenals."

Among molluscs we may mention the *Teredo navalis*, which is a native of equatorial seas, but which, by adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalized in England, and other countries enjoying an extensive commerce. *Bulimus undatus*, a land species of considerable size, native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool; and, as I learn from Mr. Broderip, is now naturalized in the woods near that town.

In all these and innumerable other instances we may regard the involuntary agency of man as strictly analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

* Syst. of Geog., vol. viii. p. 169.

CHAPTER VIII.

THEORIES RESPECTING THE ORIGINAL INTRODUCTION OF SPECIES.

Proposal of an hypothesis on this subject — Supposed centres or foci of creation — Why distinct provinces of animals and plants have not become more blended together — Brocchi's speculations on the loss of species (p. 104.) — Stations of plants and animals — Causes on which they depend — Stations of plants, how affected by animals — Equilibrium in the number of species, how preserved — Peculiar efficacy of insects in this task (p. 110.) — Rapidity with which certain insects multiply or decrease in numbers — Effect of omnivorous animals in preserving the equilibrium of species (p. 118.). — Reciprocal influence of aquatic and terrestrial species on each other.

Theory of Linnæus. — It would be superfluous to examine the various attempts which were made to explain the phenomena of the distribution of species alluded to in the preceding chapters, in the infancy of the sciences of botany, zoology, and physical geography. The theories or rather conjectures then indulged now stand refuted by a simple statement of facts; and if Linnæus were living he would be the first to renounce the notions which he promulgated. For he imagined the habitable world to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primæval ocean. In this fertile spot he supposed the

originals of all the species of plants which exist on this globe to have been congregated, together with the first ancestors of all animals and of the human race. "In quâ commodè habitaverint animalia omnia, et vegetabilia lætè germinaverint." In order to accommodate the various habitudes of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were to be found all temperatures and every climate, from that of the torrid to that of the frozen zone.*

That there never was a universal ocean since the planet was inhabited, or, rather, since the oldest groups of strata yet known to contain organic remains were formed, is proved by the presence of terrestrial plants in all the older formations; and if this conclusion was not established, yet no geologist could deny that, since the first small portion of the earth was laid dry, there have been many entire changes in the species of plants and animals inhabiting the land.

But, without dwelling on the above and other refuted theories, let us inquire whether some hypothesis cannot be substituted as simple as that of Linnæus, to which the phenomena now ascertained in regard to the distribution both of aquatic and terrestrial species may be referred. The following may, perhaps, be reconcileable with known facts:—Each species may have had its origin in a single pair, or individual,

* De terra habitabili incremento; also Prichard, Phys. Hist. of Mankind, vol. i. p. 17., where the hypotheses of different naturalists are enumerated.

where an individual was sufficient, and species may have been created in succession at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe.

In order to explain this theory, let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.

Now it is easy to show that the result of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe. In the first place, it would be necessary for naturalists, before they imported species into particular localities, to study attentively the climate and other physical conditions of each spot. It would be no less requisite to introduce the different species in succession, so that each plant and animal might have time and opportunity to multiply before the species destined to prey upon it was admitted. Many herbs and shrubs, for example, must spread far and wide before the sheep, the deer, and the goat could be allowed to enter, lest they should devour and annihilate the original stocks of many plants, and then perish themselves for want of food. The above-mentioned herbivorous animals in their turn must be permitted to make considerable progress before the entrance of the first pair of wolves or lions. Insects must be allowed to swarm before the swallow could be permitted to skim through the air, and feast on thousands at one repast.

It is evident that, however equally in this case our original stocks were distributed over the whole surface of land and water, there would nevertheless arise distinct botanical and zoological provinces, for there are a great many natural barriers which oppose common obstacles to the advance of a variety of species. Thus, for example, almost all the animals and plants naturalized by us, towards the extremity of South America, would be unable to spread beyond a certain limit, towards the east, west, and south; because they would be stopped by the ocean, and a few of them only would succeed in reaching the cooler latitudes of the northern hemisphere, because they would be incapable of bearing the heat of the tropics, through which they must pass. In the course of ages, undoubtedly, exceptions would arise, and some species might become common to the temperate and polar regions, or both sides of the equator; for I have before shown that the powers of diffusion conferred on some classes are very great. But we might confidently predict that these exceptions would never become so numerous as to invalidate the general rule.

Some of the plants and animals transplanted by us to the coast of Chili or Peru would never be able to cross the Andes, so as to reach the Eastern plains; nor, for a similar reason, would those first established in the Pampas, or the valleys of the Amazon and the Orinoco, ever arrive at the shores of the Pacific.

In the ocean an analogous state of things would prevail; for there, also, climate would exert a great influence in limiting the range of species, and the land would stop the migrations of aquatic tribes as effectually as the sea arrests the dispersion of the terrestrial.

As certain birds, insects, and the seeds of plants can never cross the direction of prevailing winds, so currents form natural barriers to the dissemination of many oceanic races. A line of shoals may be as impassable to deep-water species, as are the Alps and the Andes to plants and animals peculiar to plains; while deep abysses may prove insuperable obstacles to the migrations of the inhabitants of shallow waters.

Supposed centres, or foci, of creation. — It is worthy of observation, that one effect of the introduction of single pairs of each species must be the confined range of certain groups in spots, which, like small islands, or solitary inland lakes, have few means of interchanging their inhabitants with adjoining regions. Now this congregating, in a small space, of many peculiar species, would give an appearance of *centres* or *foci* of creation, as they have been termed, as if there were favourite points where the creative energy has been in greater action than in others, and where the numbers of peculiar organic beings have consequently become more considerable.

I do not mean to call in question the soundness of the inferences of some botanists, as to the former existence of certain limited spots whence species of plants have been propagated, radiating, as it were, in all directions from a common centre. On the contrary, I conceive these phenomena to be the necessary consequences of the plan of nature before suggested, operating during the successive mutations of the surface, some of which the geologist can prove to have taken place subsequently to the period when many species now existing were created. In order to exemplify how this arrangement of plants may have been produced, let us imagine that, about three centuries

before the discovery of St. Helena (itself of submarine volcanic origin), a multitude of new islands had been thrown up in the surrounding sea, and that these had each become clothed with plants emigrating from St. Helena, in the same manner as the wild plants of Campania have diffused themselves over Monte Nuovo. Whenever the first botanist investigated the new archipelago, he would, in all probability, find a different assemblage of plants in each of the islands of recent formation; but, in St. Helena itself, he would meet with individuals of every species belonging to all parts of the archipelago, and some, in addition, peculiar to itself, viz., those which had not been able to obtain a passage into any one of the surrounding new-formed lands. In this case, it might be truly said that the original island was the primitive focus, or centre, of a certain type of vegetation; whereas, in the surrounding islands, there would be a smaller number of species, yet all belonging to the same group.

But this peculiar distribution of plants would not warrant the conclusion that, in the space occupied by St. Helena, there had been a greater exertion of creative power than in the spaces of equal area occupied by the new adjacent lands, because, within the period in which St. Helena had acquired its peculiar vegetation, each of the spots supposed to be subsequently converted into land may have been the birth-places of a great number of *marine* animals and plants, which may have had time to scatter themselves far and wide over the southern Atlantic.

Why distinct provinces not more blended. — Perhaps it may be objected to some parts of the foregoing train of reasoning, that during the lapse of past ages, especially during many partial revolutions of the globe

of comparatively modern date, different zoological and botanical provinces ought to have become more confounded and blended together — that the distribution of species approaches too nearly to what might have been expected, if animals and plants had been introduced into the globe when its physical geography had already assumed the features which it now wears; whereas we know that, in certain districts, considerable geographical changes have taken place since species identical with those now in being were created.

Brocchi's speculations on loss of species. — These, and many kindred topics, cannot be fully discussed until we have considered, not merely the general laws which may regulate the first introduction of species, but those which may limit their *duration* on the earth. Brocchi, whose untimely death in Egypt is deplored by all who have the progress of geology at heart, has remarked, when hazarding some interesting conjectures respecting "the loss of species," that a modern naturalist had no small assurance, who declared "that individuals alone were capable of destruction, and that species were so perpetuated that nature could not annihilate them, so long as the planet lasted, or at least that nothing less than the shock of a comet, or some similar disaster, could put an end to their existence."* The Italian geologist, on the contrary, had satisfied himself, that many species of testacea, which formerly inhabited the Mediterranean, had become extinct, although a great number of others, which had been the contemporaries of those lost races, still survived. He came to the opinion, that about half the species

* Necker, Phytozool. Philosoph., p. 21. Brocchi, Conch. Foss. Subap., tome i. p. 229.

which peopled the waters when the Subapennine strata were deposited had gone out of existence; and in this inference he does not appear to have been far wrong.

But, instead of seeking a solution of this problem, like some other geologists of his time, in a violent and general catastrophe, Brocchi endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiaries of constitution conferred upon them at their birth; and as the longevity of the one depends on a certain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species, which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, "until that fatal term arrives when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated, — and so all dies with it."

Now we might coincide in opinion with the Italian naturalist, as to the gradual extinction of species one after another, by the operation of regular and constant causes, without admitting an inherent principle of deterioration in their physiological attributes. We might concede, "that many species are on the decline, and that the day is not far distant when they will cease to exist;" yet deem it consistent with what we know of the nature of organic beings, to believe that

the last individuals of each species retain their prolific powers in their full intensity.

Brocchi has himself speculated on the share which a change of climate may have had in rendering the Mediterranean unfit for the habitation of certain testacea, which still continued to thrive in the Indian Ocean, and of others which were now only represented by analogous forms within the tropics. He must also have been aware that other extrinsic causes, such as the progress of human population, or the increase of some one of the inferior animals, might gradually lead to the extirpation of a particular species, although its fecundity might remain to the last unimpaired. If, therefore, amid the vicissitudes of the animate and inanimate world, there are known causes capable of bringing about the decline and extirpation of species, it became him thoroughly to investigate the full extent to which these might operate, before he speculated on any cause of so purely hypothetical a kind as "the diminution of the prolific virtue."

If it could have been shown that some wild plant had insensibly dwindled away and died out, as sometimes happens to cultivated varieties propagated by cuttings, even though climate, soil, and every other circumstance should continue identically the same — if any animal had perished while the physical condition of the earth, and the number and force of its foes, with every other extrinsic cause, remained unaltered, then might we have some ground for suspecting that the infirmities of age creep on as naturally on species as upon individuals. But, in the absence of such observations, let us turn to another class of facts, and examine attentively the circumstances which determine the

stations of particular animals and plants, and perhaps we shall discover, in the vicissitudes to which these stations are exposed, a cause fully adequate to explain the phenomena under consideration.

Stations of plants and animals.—Stations comprehend all the circumstances, whether relating to the animate or inanimate world, which determine whether a given plant or animal can exist in a given place; so that if it be shown that stations can become essentially modified by the influence of known causes, it will follow that species, as well as individuals, are mortal.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than three thousand species of plants, ten thousand insects, and a great variety in each of the other classes; yet there will not be more than a hundred, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed tract: it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of their power of diffusion, of invading adjacent territories.

The principal causes which enable a certain assemblage of plants thus to maintain their ground against all others depend, as is well known, on the relations between the physiological nature of each species, and the climate, exposure, soil, and other physical con-

ditions of the locality. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass,—others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so fatal to the generality of species, affords the most proper station. The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendancy over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and, as in the case of heaths, live in societies. In like manner the Bog moss (*Sphagnum palustre*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but each plant, for reasons not fully explained by the physiologist, has the property of rendering the soil where it has grown less fitted for the support of other individuals of its own species, or even other species of the same family. Yet the same spot, so far from being impoverished, is improved, for plants of *another* family. Animals also interfere most actively to preserve an equilibrium in the vegetable kingdom.

Equilibrium in the number of species, how preserved.—" All the plants of a given country," says De Can-

dolle, in his usual spirited style, "are at war one with another. The first which establish themselves by chance in a particular spot tend, by the mere occupancy of space, to exclude other species — the greater choke the smaller; the longest livers replace those which last for a shorter period; the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill."

In this continual strife, it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, a herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure; because its leaves are unpalatable to cattle, which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the open fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may, nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with seeds which perpetuate the species throughout the surrounding tract.

In the above example we see one plant shielding another from the attacks of animals; but instances are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom.

Scarcely any beast, observes a Swedish naturalist, will touch the nettle, but fifty different kinds of insects are fed by it.* Some of these seize upon the root, others upon the stem; some eat the leaves; others devour the seeds and flowers: but for this multitude of enemies, the nettle would annihilate a great number of plants. Linnæus tells us, in his Tour in Scania, that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet, and water-hemlock, plants which are injurious to cattle.†

Agency of insects. — Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. "Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the Phalæna graminis (*Bombyx gram.*), with her numerous progeny, find a well-spread table; they multiply in immense numbers, and the farmer for some years laments the failure of his crop; but, the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the other plants, which were before choked by it, spring up, and the ground be-

* Amœn. Acad. vol. vi. p. 17. § 12.

† Ibid., vol. vii. p. 409.

comes variegated with a multitude of different species of flowers. Had not nature given a commission to this minister for that purpose, the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up." *

In the above passage allusion is made to the ravages committed in 1740 and the two following years in many provinces in Sweden, by a most destructive insect. The same moth is said never to touch the fox-tail grass, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance.† A discovery of Rolander, cited in the treatise of Wilcke above mentioned, affords a good illustration of the checks and counter-checks which nature has appointed to preserve the balance of power amongst species. "The Phalæna strobilella has the fir cone assigned to it to deposit its eggs upon; the young caterpillars coming out of the shell consume the cone and superfluous seed; but, lest the destruction should be too general, the Ichneumon strobilellæ lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched destroys it." ‡

Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly appointed to prey on them.§ Few, perhaps, are in the habit of duly appreciating the extent to which

* Amœn. Acad., vol. vi. p. 17. § 11, 12.

† Kirby and Spence, vol. i. p. 178.

‡ Amœn. Acad., vol. vi. § 14.

§ Kirby and Spence, vol. iv. p. 218.

insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals.

The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing, without the intervention of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which nature has been so prodigal. A scanty number of minute individuals, to be detected only by careful research, are ready in a few days, weeks, or months, to give birth to myriads, which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been executed than the gigantic power becomes dormant — each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either

by the elements, or by the augmentation of some of its numerous foes which may prey upon it in these stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their strength, and then, like Milton's spirits, which thronged the spacious hall, "reduce to smallest forms their shapes immense"—

> ———— So thick the aëry crowd
> Swarm'd and were straiten'd; till, the signal given,
> Behold a wonder! they but now who seem'd
> In bigness to surpass earth's giant sons,
> Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable matter; and, upon considering a catalogue of eight thousand British insects and arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some appointed to consume living, others dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give birth to twenty thousand young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there

was ground, says Kirby, for the assertion of Linnæus, that three flies of M. vomitoria could devour a dead horse as quickly as a lion*; and another Swedish naturalist remarks, that so great are the powers of propagation of a single species, even of the smallest insects, that each can commit, when required, more ravages than the elephant.†

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations.‡ Mr. Curtis observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides: some are particular, others more general, feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than in others.§ In 1793 they were the chief, and in 1798 the sole, cause of the failure of the hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them; while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller

* Kirby and Spence, vol. i. p. 250.

† Wilcke, Amœn. Acad., chap. ii.

‡ Kirby and Spence, vol. i. p. 174.

§ Trans. Linn. Soc., vol. vi.

moths afford a good illustration of the temporary increase of a species. The oak-trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix viridana*), which has been observed the year following not to abound.* The Gamma moth (*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations; but legions of their caterpillars have at times created alarm in France, as in 1735. Reaumur observes that the female moth lays about four hundred eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if all fertile, would produce more than three million moths.† A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the two thousand other British species, would soon destroy more than half of our vegetation.‡

In the latter part of the last century an ant, most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Granada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and roads were filled with them; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by

* Lib. Ent. Know., Insect Trans., p. 203. See Haworth, Lep.

† Reaumur, ii. 237.

‡ Lib. Ent. Know., Insect Trans., p. 212.

torrents of rain, which accompanied a dreadful hurricane.‡

Devastations caused by locusts. — We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures, which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the famine they occasioned. St. Augustin mentions a plague of this kind in Africa which destroyed no less than 800,000 men in the kingdom of Masinissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591 an infinite army of locusts migrated from Africa into Italy; and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

In the Venetian territory, also, in 1478, more than thirty thousand persons are said to have perished in a famine occasioned by this scourge; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland,— in Arabia and India, and other countries, — their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter

* Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in southern Africa, they were driven into the sea by a north-west wind, they formed, says Barrow, along the shore, for fifty miles, a bank three or four feet high.* But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in the temperate zone, affect the proportional numbers of almost all classes of animals and plants, and are probably fatal to the existence of many which would otherwise thrive there; while, on the contrary, they must be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this does not always happen; partly because many species feed in common on the same kinds of food, and partly because many kinds of food are often consumed indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of these insects may cause only a slight and almost imperceptible augmentation of each of these species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where our English buzzards devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, by which means the balance may be restored.

Agency of omnivorous animals.—The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus, when the racoon of the West Indies can procure neither fowls, fish, snails, nor insects, it will attack the sugar-canes, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots.

Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous, and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians, Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species.—The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated causes which determine the existence of animals and plants in certain regions. A large portion of the amphibious quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connexion between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the sea-shore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years the otters at the distance of several hundred miles

inland will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate a greater number of illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances, — on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed on certain plants, being often restricted to a small number, and sometimes to one only; other members of the animal kingdom feed on plant-eating species, and thus become dependent on the conditions of the *stations* not only of their prey, but of the plants consumed by them.

Having duly reflected on the nature and extent of these mutual relations in the different parts of the organic and inorganic worlds, we may next proceed to examine the results which may be anticipated from the fluctuations now continually in progress in the state of the earth's surface, and in the geographical distribution of its living productions.

CHAPTER IX.

THE CIRCUMSTANCES WHICH CONSTITUTE THE STATIONS OF ANIMALS ARE CHANGEABLE.

Extension of the range of one species alters the condition of many others — The first appearance of a new species causes the chief disturbance — Changes known to have resulted from the advance of human population (p. 127.) — Whether man increases the productive powers of the earth — Indigenous quadrupeds and birds extirpated in Great Britain — Extinction of the Dodo (p. 133.) — Rapid propagation of domestic quadrupeds in America — Power of exterminating species no prerogative of man (p. 139.) — Concluding remarks.

We have seen that the stations of animals and plants depend not merely on the influence of external agents in the inanimate world, and the relations of that influence to the structure and habits of each species, but also on the state of the contemporary living beings which inhabit the same part of the globe. In other words, the possibility of the existence of a certain species in a given place, or of its thriving more or less therein, is determined not merely by temperature, humidity, soil, elevation, and other circumstances of the like kind; but also by the existence or non-existence, the abundance or scarcity, of a particular assemblage of other plants and animals in the same region.

If it be shown that both these classes of circumstances, whether relating to the animate or inanimate creation, are perpetually changing, it will follow that species are subject to incessant vicissitudes; and if the

result of these mutations, in the course of ages, be so great as materially to affect the general condition of *stations*, it will follow that the successive destruction of species must now be part of the regular and constant order of nature.

Extension of the range of one species alters the condition of others.—It will be desirable, first, to consider the effects which every extension of the numbers or geographical range of one species must produce on the condition of others inhabiting the same regions. When the necessary consequences of such extensions have been fully explained, the reader will be prepared to appreciate the important influence which slight modifications in the physical geography of the globe may exert on the condition of organic beings.

In the first place, it is clear that when any region is stocked with as great a variety of animals and plants as the productive powers of that region will enable it to support, the addition of any new species, or the *permanent* numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way: but whilst the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the fact that, when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

> The darnel, hemlock, and rank fumitory,

pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we inclose a park, and stock it with as many deer as the herbage will support, we cannot add sheep without lessening the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey, and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, this may deprive a large number of plant-eating animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey; certain species, perhaps, which had the weakest footing in the island may thus be annihilated.

We have seen how many distinct geographical provinces there are of aquatic and terrestrial species, and how great are the powers of migration conferred on different classes, whereby the inhabitants of one region may be enabled from time to time to invade another, and do actually so migrate and diffuse themselves over new countries. Now, although our knowledge of the history of the animate creation dates from so

recent a period, that we can scarcely trace the advance or decline of any animal or plant, except in those cases where the influence of man has intervened; yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the polar bear into Iceland.—Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms—each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm; nor did our islanders muster more promptly for the defence of their lives and property against a common enemy, than the modern Icelanders against these formidable brutes. It often happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been heightened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape.*

Let us cast our thoughts back to the period when the first polar bears reached Iceland, before it was colonized by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice, like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had sur-

* Journal of a Residence in Iceland, p.276.

rounded for four centuries. By the aid of such means of transportation a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region; and the changes caused indirectly would ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation, its nests

being seldom if ever found on the shores of the main land, or even of a large island. The Icelanders are so well aware of this, that they have expended a great deal of labour in forming artificial islands, by separating from the main land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Hooker, it happened that, in the small island of Vidoe, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alarm, as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.*

The first appearance of a new species causes the chief disturbance. — It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitively settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two centuries a frost of unusual intensity, or a volcanic erup-

* Tour in Iceland, vol. i. p. 64., second edition.

tion of great violence accompanied by floods from the melting of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others, — these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comer, such as the bear before mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, or an epidemic disease, may pass away without any great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at preceding periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by an epidemic or by famine, caused by the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

Changes caused by Man.

We are best acquainted with the mutations brought about by the progress of human population, and the

growth of plants and animals favoured by man. To these, therefore, we should in the first instance turn our attention. If we conclude, from the concurrent testimony of history and of the evidence yielded by geological data, that man is, comparatively speaking, of very modern origin, we must at once perceive how great a revolution in the state of the animate world the increase of the human race, considered merely as consumers of a certain quantity of organic matter, must necessarily cause.

Whether man increases the productive powers of the earth. — It may, perhaps, be said, that man has, in some degree, compensated for the appropriation to himself of so much food, by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt whether, upon the whole, we fertilize or impoverish the lands which we occupy. This assertion may seem startling to many; because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass is converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface — that we have not empowered it to support a larger quantity of organic life. In such cases, however, a tract, before of no utility to man, may be reclaimed, and become of high agricultural importance, though it may, nevertheless, yield a scantier vegetation. If a lake be drained, and turned into a meadow, the space will provide sustenance to man, and many terrestrial animals serviceable

to him, but not, perhaps, so much food as it previously yielded to the aquatic races.

If the pestiferous Pontine Marshes were drained, and covered with corn, like the plains of the Po, they might, perhaps, feed a smaller number of animals than they do now; for these morasses are filled with herds of buffaloes and swine, and they swarm with birds, reptiles, and insects.

The felling of dense and lofty forests, which covered, even within the records of history, a considerable space on the globe, now tenanted by civilized man, must generally have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilizing effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti,

and wild swine. They describe the torment which the planter and the naturalist suffer from the musquitoes, and the devastation of the ants and blattæ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, lizards, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, observe these naturalists, these evils will gradually diminish; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will, by degrees, triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity.*

The number of human beings now peopling the earth is supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds, and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

Indigenous quadrupeds and birds extirpated in Great Britain.—Let us make some inquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of indigenous British animals. Dr. Fleming has prosecuted this inquiry with his usual zeal and ability; and in a memoir on the subject has enumerated the best authenticated examples of the decrease or extirpation of certain species during a

* Travels in Brazil, vol. i. p. 260.

period when our population has made the most rapid advances. I shall offer a brief outline of his results.*

The stag, as well as the fallow deer and the roe, were formerly so abundant in our island, that, according to Lesley, from five hundred to a thousand were sometimes slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the pole-cat, were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district which at former periods they inhabited.

Besides these, which have been driven out from some haunts, and every where reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, and the wild boar; of the wild oxen, a few remains are still preserved in the parks of some of our nobility. The beaver, which was eagerly sought after for its fur, had become scarce at the close of the ninth century; and, by the twelfth century, was only to be met with, according to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England

* Ed. Phil. Journ., No. xxii. p. 287. Oct. 1824.

at a much earlier period. The bear, which, in Wales, was regarded as a beast of the chase equal to the hare or the boar*, only perished, as a native of Scotland, in the year 1057.†

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British isles; whereas the large capercailzies, or wood grouse, formerly natives of the pine-forests of Ireland and Scotland, have been destroyed within the last fifty years. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants.‡

The bustard (*Otis tarda*), observes Graves, in his British Ornithology §, "was formerly seen in the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now a circumstance of rare occurrence to meet with a single individual." Bewick also remarks, "that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east — in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire." In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from Wiltshire and Dorsetshire.‖

These changes, it may be observed, are derived

* Ray, Syn. Quad., p. 214.

† Fleming, Ed. Phil. Journ., No. xxii. p. 295.

‡ Fleming, ibid., p. 292.

§ Vol. iii., London, 1821.

‖ Land Birds, vol. i. p. 316. ed. 1821.

from very imperfect memorials, and relate only to the larger and more conspicuous animals inhabiting a small spot on the globe; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of several thousand years, the whole human species must have effected.

Extinction of the Dodo.—The kangaroo and the emu are retreating rapidly before the progress of colonization in Australia; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last two centuries, of a remarkable species, is that of the dodo — a bird first seen by the Dutch, when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size, and singular form; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.

Many naturalists gave figures of the dodo after the commencement of the seventeenth century; and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head, in an imperfect state; but M. Cuvier doubts the identity of this species with that of which the painting is preserved in London.

In spite of the most active search, during the last century, no information respecting the dodo was ob-

tained, and some authors have gone so far as to pretend that it never existed; but, amongst a great mass of satisfactory evidence in favour of the recent existence of this species, we may mention that an assemblage of fossil bones were recently discovered, under a bed of lava, in the Isle of France, and sent to the Paris Museum by M. Desjardins. They almost all belonged to a large living species of land-tortoise, called *Testudo Indica;* but amongst them were the head, sternum, and humerus of the dodo. M. Cuvier showed me these valuable remains in Paris, and assured me that they left no doubt in his mind that the huge bird was one of the gallinaceous tribe.*

Rapid propagation of domestic quadrupeds over the American continent. — Next to the direct agency of man, his indirect influence in multiplying the numbers of large herbivorous quadrupeds of domesticated races may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three centuries, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which overran the plains of South America sprung from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels, on the authority

* Sur quelques Ossemens, &c. — Ann. des Sci., tome xxi. p. 103. Sept. 1830.

of Azzara, that it is believed there exist, in the Pampas of Buenos Ayres, twelve million cows and three million horses, without comprising, in this enumeration, the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as fourteen thousand a year.* In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that 1,200,000 oxen, 180,000 horses, and 90,000 mules, wandered at large.† In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses are immensely numerous.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of four thousand head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to eight thousand. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was 35,444; and in the same year there were exported 64,350 from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into

* Pers. Nar., vol. iv.

† Quarterly Review, vol. xxi. p. 335.

that country, had not been able to engage in any thing else than war.*

Every one is aware that these animals are now established throughout the American continent, from Canada to Paraguay.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked defended themselves with their mouths. If a horse happened to stray into the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead.†

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery, in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled; and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat; which last, as before stated, has been imported unintentionally in ships. The dogs introduced by man, which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Ulloa in his Voyage, and Buffon on the authority of

* Quarterly Review, vol. xxi. p. 335.

† Ulloa's Voyage. Wood's Zoog., vol. i. p. 9.

old writers, relate a fact which illustrates very clearly the principle before explained, of the check which the increase of one animal necessarily offers to that of another. The Spaniards had introduced goats into the island of Juan Fernandez, where they became so prolific as to furnish the pirates who infested those seas with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased.*

Increase of rein-deer imported into Iceland. — As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, I may mention, that in the year 1773 thirteen rein-deer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty years, that it was not uncommon to meet with herds, consisting of from forty to one hundred, in various districts.

In Lapland, observes a modern writer, the rein-deer is a loser by his connexion with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than forty thousand square miles, without a single human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the rein-deer, being almost unmolested by man, will have no enemy

* Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

whatever, unless it has brought with it its own tormenting gadfly.*

Besides the quadrupeds before enumerated, our domestic fowls have also succeeded in the West Indies and America, where they have the common fowl, the goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations they became familiarized to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries.

The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe. That it should have remained for us to witness such mighty revolutions is a proof, even if there was no other evidence, that the entrance of man into the planet is, comparatively speaking, of extremely modern date, and that the effects of his agency are only beginning to be felt.

Population which the globe is capable of supporting.— A modern writer has estimated, that there are in America upwards of four million square miles of use-

* Travels in Iceland in 1810, p. 342.

ful soil, each capable of supporting 200 persons; and nearly six million, each mile capable of supporting 490 persons.* If this conjecture be true, it will follow, as that author observes, that if the natural resources of America were fully developed, it would afford sustenance to five times as great a number of inhabitants as the entire mass of human beings existing at present upon the globe. The new continent, he thinks, though less than half the size of the old, contains an equal quantity of useful soil, and much more than an equal amount of productive power. Be this as it may, we may safely conclude that the amount of human population now existing constitutes but a small proportion of that which the globe is capable of supporting, or which it is destined to sustain at no distant period, by the rapid progress of society, especially in America, Australia, and certain parts of the old continent.

Power of exterminating species no prerogative of man. — But if we reflect that many millions of square miles of the most fertile land, occupied originally by a boundless variety of animal and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly civilized nations spread themselves over unoccupied lands.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc

* Maclaren, art. America, Encyc. Britannica.

committed, nor to fancy, with the Scottish poet, that "we violate the social union of nature;" or complain, with the melancholy Jaques, that we

> Are mere usurpers, tyrants, and what's worse,
> To fright the animals and to kill them up
> In their assign'd and native dwelling-place.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called "the rust" in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the "lords of the creation." The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks.—Although we have as yet considered one class only of the causes (the organic) by which species may become exterminated, yet it cannot but appear evident that the continued action of these alone, throughout myriads of future ages, must work an entire change in the state of the organic creation, not merely on the continents and islands, where the power of man is chiefly exerted, but in the great ocean, where his controul is almost unknown. The mind is prepared by the contemplation of such future revolu-

tions to look for the signs of others, of an analogous nature, in the monuments of the past. Instead of being astonished at the proofs there manifested of endless mutations in the animate world, they will appear to one who has thought profoundly on the fluctuations now in progress, to afford evidence in favour of the uniformity of the system, unless, indeed, we are precluded from speaking of *uniformity* when we characterize a principle of endless variation.

CHAPTER X.

INFLUENCE OF INORGANIC CAUSES IN CHANGING THE HABITATIONS OF SPECIES.

Powers of diffusion indispensable, that each species may maintain its ground — How changes in the physical geography affect the distribution of species — Rate of the change of species due to this cause cannot be uniform (p. 145.) — Every change in the physical geography of large regions tends to the extinction of species (p. 152.) — Effects of a general alteration of climate on the migration of species — Gradual refrigeration would cause species in the northern and southern hemispheres to become distinct — elevation of temperature the reverse — Effects on the condition of species which must result from inorganic changes inconsistent with the theory of transmutation (p. 161).

Powers of diffusion indispensable, that each species may maintain its ground. — HAVING shown in the last chapter how considerably the numerical increase or the extension of the geographical range of any one species must derange the numbers and distribution of others, let us now direct our attention to the influence which the inorganic causes described in the second book are continually exerting on the habitations of species.

So great is the instability of the earth's surface, that if naturé were not continually engaged in the task of sowing seeds and colonizing animals, the depopulation of a certain portion of the habitable sea and land

would in a few years be considerable. Whenever a river transports sediment into a lake or sea, so as materially to diminish its depth, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain useless; but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river banishes many subaqueous species from their native abodes; but the new-formed plain is not permitted to lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coast, and precipitates forests or rich pasture land into the waves: but this space is not lost to the animate creation; for shells and sea-weed soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic island been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure, while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks, pines, and chestnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every

advance of the sand-flood, every conversion of salt-water into fresh when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary — these and countless other causes displace, in the course of a few centuries, certain plants and animals from stations which they previously occupied. If, therefore, the Author of nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth — if he had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the dark abysses of the ocean, or the moving sands of the Sahara.

The powers then of migration and diffusion conferred on animals and plants are indispensable to enable them to maintain their ground, and would be necessary even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other, since the strongest of those barriers which I before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

How changes in physical geography affect the distribution of species. — The numbers and distribution of particular species are affected in two ways, by changes in the physical geography of the earth:—First, these changes promote or retard the migrations of species; secondly, they alter the physical conditions of the

localities which species inhabit. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas previously disjoined, and would, at the same time, close a free communication which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land which formed the isthmus into sea. This space, previously occupied by terrestrial plants and animals, would be immediately delivered over to the aquatic; a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of species of two distinct provinces.

Rate of change of species cannot be uniform. — This observation leads me to point out one of the most interesting conclusions to which we are led by the contemplation of the vicissitudes of the inanimate world in relation to those of the animate. It is clear that, if the agency of inorganic causes be uniform, as I have supposed, they must operate very irregularly on the state of organic beings, so that the rate according to which these will change in particular regions will not be equal in equal periods of time.

I am not about to advocate the doctrine of general catastrophes recurring at certain intervals, as in the ancient Oriental cosmogonies, nor do I doubt that, if very considerable periods of equal duration could be compared one with another, the rate of change in the

living, as well as in the inorganic world, might be nearly uniform; but if we regard each of the causes separately, which we know to be at present the most instrumental in remodelling the state of the surface, we shall find that we must expect each to be in action for thousands of years, without producing any extensive alterations in the habitable surface, and then to give rise, during a very brief period, to important revolutions.

Illustration derived from subsidences. — I shall illustrate this principle by a few of the most remarkable examples which present themselves. In the course of the last century, as we have seen, a considerable number of instances are recorded of the solid surface, whether covered by water or not, having been permanently sunk or upraised by subterranean movements. Most of these convulsions are only accompanied by temporary fluctuations in the state of limited districts, and a continued repetition of these events for thousands of years might not produce any decided change in the state of many of those great zoological or botanical provinces of which I have sketched the boundaries.

When, for example, large parts of the ocean and even of inland seas are a thousand fathoms or upwards in depth, it is a matter of no moment to the animate creation that vast tracts should be heaved up many fathoms at certain intervals, or should subside to the same amount. Neither can any material revolution be produced in South America either in the terrestrial or the marine plants or animals by a series of shocks on the coast of Chili, each of which, like that of Penco, in 1750, should uplift the coast about twenty-five feet. Nor if the ground sinks fifty feet at a time, as in the harbour of Port Royal, in Jamaica, in 1692, will such

alterations of level work any general fluctuations in the state of organic beings inhabiting the West India islands, or the Caribbean Sea.

It is only when these subterranean powers, by shifting gradually the points where their principal force is developed, happen to strike upon some particular region where a slight change of level immediately affects the distribution of land and water, or the state of the climate, or the barriers between distinct groups of species over extensive areas, that the rate of fluctuation becomes accelerated, and may, in the course of a few years or centuries, work mightier changes than had been experienced in myriads of antecedent years.

Thus, for example, a repetition of subsidences causing the narrow isthmus of Panamá to sink down a few hundred feet, would, in a few centuries, bring about a great revolution in the state of the animate creation in the western hemisphere. Thousands of aquatic species would pass, for the first time, from the Caribbean Sea into the Pacific; and thousands of others, before peculiar to the Pacific Ocean, would make their way into the Caribbean Sea, the Gulf of Mexico, and the Atlantic. A considerable modification would probably be occasioned by the same event in the direction or volume of the Gulf stream, and thereby the temperature of the sea and the contiguous lands might be altered as far as the influence of that current extends. A change of climate might thus be produced in the ocean from Florida to Spitzbergen, and in many countries of North America, Europe, and Greenland. Not merely the heat, but the quantity of rain which falls, would be altered in certain districts, so that many species would be excluded from tracts where they before flourished; others would be reduced in number; and some would thrive more and

multiply. The seeds also and the fruits of plants would no longer be drifted in precisely the same directions, nor the eggs of aquatic animals; neither would species be any longer impeded in their migrations towards particular stations before shut out from them by their inability to cross the mighty current.

Let us take another example from a part of the globe which is at present liable to suffer by earthquakes, namely, the low sandy tract which intervenes between the Sea of Azof and the Caspian. If there should occur a sinking down to a trifling amount, and such ravines should be formed as might be produced by a few earthquakes, not more considerable than have fallen within our limited observation during the last 140 years, the waters of the Sea of Azof would pour rapidly into the Caspian, which, according to the levellings of the Russian travellers Engelhardt and Parrot, is about 350 feet below the level of the Black Sea.* The Sea of Azof would immediately borrow from the Black Sea, that sea again from the Mediterranean, and the Mediterranean from the Atlantic, so that an inexhaustible current would pour down into the low tracts of Asia bordering the Caspian, by which all the sandy salt steppes adjacent to that sea would be inundated. An area of at least eighteen thousand square leagues, now below the level of the Mediterranean, would be converted from land into sea.

The diluvial waters would reach the salt lake of Aral, nor stop until their eastern shores were bounded by the high land which in the steppe of the Kirghis connects the Altay with the Himalaya Mountains. Saratof, Orenburg, and the low regions of the Oxus and Jaxartes, would be submerged. A few years, perhaps a few

* Reise in den Kaukasus.

months, might suffice for the accomplishment of this great revolution in the geography of the interior of Asia; and it is impossible for those who believe in the permanence of the energy with which existing causes now act, not to anticipate analogous events again and again in the course of future ages.

Illustration derived from the elevation of land.— Let us next imagine a few cases of the elevation of land of small extent at certain critical points, as, for example, in the shallowest parts of the Straits of Gibraltar, where the soundings from the African to the European side give only 220 fathoms. In proportion as this submarine barrier of rock was upheaved, to effect which would merely require the shocks of partial and confined earthquakes, the volume of water which pours in from the Atlantic into the Mediterranean would be lessened. But the loss of the inland sea by evaporation would remain the same; so that being no longer able to draw on the ocean for a supply sufficient to restore its equilibrium, it must sink, and leave dry a certain portion of land around its borders. The current which now flows constantly out of the Black Sea into the Mediterranean would then rush in more rapidly, and the level of the Mediterranean would be thereby prevented from falling so low; but the level of the Black Sea would, for the same reason, sink; so that when, by a continued series of elevatory movements, the Straits of Gibraltar had become completely closed up, we might expect large and level sandy steppes to surround both the Black Sea and Mediterranean, like those occurring at present on the skirts of the Caspian, and the Lake of Aral. The geographical range of hundreds of aquatic species would be thereby circumscribed, and that of hundreds of terrestrial plants and animals extended.

A line of submarine volcanos crossing the channel of some strait, and gradually choking it up with ashes and lava, might produce a new barrier as effectually as a series of earthquakes; especially if thermal springs, charged with carbonate of lime, silica, and other mineral ingredients, should promote the rapid multiplication of corals and shells, and cement them together with solid matter precipitated during the intervals between eruptions. Suppose in this manner a stoppage to be caused of the Bahama Channel between the bank of that name and the coast of Florida. This insignificant revolution, confined to a mere spot in the bottom of the ocean, would, by diverting the main current of the Gulf stream, give rise more effectually than the opening of the Straits of Panamá, before supposed, to extensive changes in the climate and distribution of animals and plants inhabiting the northern hemisphere.

Illustration from the formation of new islands. — A repetition of elevatory movements of earthquakes might continue over an area as extensive as Europe, for thousands of ages, at the bottom of the ocean, in certain regions, and produce no visible effects; whereas, if they should operate in some shallow parts of the Pacific, amid the coral archipelagos, they would soon give birth to a new continent. Hundreds of volcanic islands may be thrown up, and become covered with vegetation, without causing more than local fluctuations in the animate world; but if a chain like the Aleutian archipelago, or the Kurile Isles, run for a distance of many hundred miles, so as to form an almost uninterrupted communication between two continents, or two distant islands, the migrations of plants, birds, insects, and even of some quadrupeds, may cause, in a short time, an extraordinary series of revolutions

tending to augment the range of some animals and plants, and to limit that of others. A new archipelago might be formed in the Mediterranean, the Bay of Biscay, and a thousand other places, and might produce less important events than one rock which should rise up between Australia and Java, so placed that winds and currents might cause an interchange of the plants, insects, and birds.

From the wearing through of an isthmus.—If we turn from the igneous to the aqueous agents, we find the same tendency to an irregular rate of change, naturally connected with the strictest uniformity in the energy of those causes. When the sea, for example, gradually encroaches upon both sides of a narrow isthmus, as that of Sleswick, separating the North Sea from the Baltic, where, as before stated, the cliffs on both the opposite coasts are wasting away *, no material alteration results for thousands of years, save only that there is a progressive conversion of a small strip of land into water. A few feet only, or a few yards, are annually removed; but when, at last, the partition shall be broken down, and the tides of the ocean shall enter by a direct passage into the inland sea, instead of going by a circuitous route through the Cattegat, a body of salt water will sweep up as far as the Gulfs of Bothnia and Finland, the waters of which are now brackish, or almost fresh; and this revolution will be attended by the local annihilation of many species.

Similar consequences must have resulted, on a small scale, when the sea opened its way through the isthmus of Staveren in the thirteenth century, forming a union between an inland lake and the ocean, and

* See p. 59.

opening, in the course of one century, a shallow strait, more than half as wide as the narrowest part of that which divides England from France.

Changes in physical geography which must occasion extinction of species. — It will almost seem superfluous, after I have thus traced the important modifications in the condition of living beings which flow from changes of trifling extent, to argue that entire revolutions might be brought about, if the climate and physical geography of the whole globe were greatly altered. It has been stated, that species are in general local, some being confined to extremely small spots, and depending for their existence on a combination of causes, which, if they are to be met with elsewhere, occur only in some very remote region. Hence it must happen that, when the nature of these localities is changed, the species will perish; for it will rarely happen that the cause which alters the character of the district will afford new facilities to the species to establish itself elsewhere.

African desert. — If we attribute the origin of a great part of the desert of Africa to the gradual progress of moving sands, driven eastward by the westerly winds, we may safely infer that a variety of species must have been annihilated by this cause alone. The sand-flood has been inundating, from time immemorial, the rich lands on the west of the Nile; and we have only to multiply this effect a sufficient number of times, in order to understand how, in the lapse of ages, a whole group of terrestrial animals and plants may become extinct.

This desert, without including Bornou and Darfour, extends, according to the calculation of Humboldt, over 194,000 square leagues; an area nearly three times as great as that of France. In a small portion

of so vast a space, we may infer from analogy that there were many peculiar species of plants and animals which must have been banished by the sand, and their habitations invaded by the camel, and by birds and insects formed for the arid sands.

There is evidently nothing in the nature of the catastrophe to favour the escape of the former inhabitants to some adjoining province; nothing to weaken, in the bordering lands, that powerful barrier against emigration—pre-occupancy. Nor, even if the exclusion of a certain group of species from a given tract were compensated by an extension of their range over a new country, would that circumstance tend to the conservation of species in general; for the extirpation would merely then be transferred to the region so invaded. If it be imagined, for example, that the aboriginal quadrupeds, birds, and other animals of Africa, emigrated in consequence of the advance of drift-sand, and colonized Arabia, the indigenous Arabian species must have given way before them, and have been reduced in number or destroyed.

Let us next suppose that, in some central and more elevated parts of the great African desert, the upheaving power of subterranean movements should be exerted throughout an immense series of ages, accompanied, at certain intervals, by volcanic eruptions, such as gave rise at once, in 1755, to a mountain 1600 feet high, on the Mexican plateau. When the continued repetition of these events had caused a mountain-chain, it is obvious that a complete transformation in the state of the climate would be brought about throughout a vast area.

We may imagine the summits of the new chain to rise so high as to be covered, like Mount Atlas, for

several thousand feet, with snow, during a great part of the year. The melting of these snows, during the greatest heat, would cause the rivers to swell in the season when the greatest drought now prevails; the waters, moreover, derived from this source, would always be of lower temperature than the surrounding atmosphere, and would thus contribute to cool the climate. During the numerous earthquakes and volcanic eruptions supposed to accompany the gradual formation of the chain, there would be many floods caused by the bursting of temporary lakes, and by the melting of snows by lava. These inundations might deposit alluvial matter far and wide over the original sands, as the country assumed various shapes, and was modified again and again by the moving power from below, and the aqueous erosion of the surface above. At length the Sahara might be fertilized, irrigated by rivers and streamlets intersecting it in every direction, and covered by jungle and morasses; so that the animals and plants which now people Northern Africa would disappear, and the region would gradually become fitted for the reception of a population of species perfectly dissimilar in their forms, habits, and organization.

There are always some peculiar and characteristic features in the physical geography of each large division of the globe; and on these peculiarities the state of animal and vegetable life is dependent. If, therefore, we admit incessant fluctuations in the physical geography, we must, at the same time, concede the successive extinction of terrestrial and aquatic species to be part of the economy of our system. When some great class of *stations* is in excess in certain latitudes, as, for example, in wide savannahs, arid

sands, lofty mountains, or inland seas, we find a corresponding development of species adapted for such circumstances. In North America, where there is a chain of vast inland lakes of fresh water, we find an extraordinary abundance and variety of aquatic birds, fresh-water fish, testacea, and small amphibious reptiles, fitted for such a climate. The greater part of these would perish if the lakes were destroyed,—an event that might be brought about by some of the least of those important revolutions contemplated in geology. It might happen that no fresh-water lakes of corresponding magnitude might then exist on the globe; or that, if they occurred elsewhere, they might be situated in New Holland, Southern Africa, Eastern Asia, or some region so distant as to be quite inaccessible to the North American species; or they might be situated within the tropics, in a climate uninhabitable by species fitted for a temperate zone; or, finally, we may presume that they would be pre-occupied by *indigenous* tribes.

To pursue this train of reasoning farther is unnecessary; the geologist has only to reflect on what has been said of the habitations and stations of organic beings in general, and to consider them in relation to those effects which were contemplated in the second book, as resulting from the igneous and aqueous causes now in action, and he will immediately perceive that, amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish, one after the other, like the individuals which compose them. There is no possibility of escaping from this conclusion, without resorting to some hypothesis as violent as that of Lamarck, who imagined, as we have before seen, that species are each of them endowed with indefinite

powers of modifying their organization, in conformity to the endless changes of circumstances to which they are exposed.

Effects of a general Alteration in Climate on the Distribution of Species.

Some of the effects which must attend every general alteration of *climate* are sufficiently peculiar to claim a separate consideration before concluding the present chapter.

I have before stated that, during seasons of extraordinary severity, many northern birds, and in some countries many quadrupeds, migrate southwards. If these cold seasons were to become frequent, in consequence of a gradual and general refrigeration of the atmosphere, such migrations would be more and more regular, until, at length, many animals, now confined to the arctic regions, would become the tenants of the temperate zone; while the inhabitants of the temperate zone would approach nearer to the equator. At the same time, many species previously established on high mountains would begin to descend, in every latitude, towards the middle regions; and those which were confined to the flanks of mountains would make their way into the plains. Analogous changes would also take place in the vegetable kingdom.

If, on the contrary, the heat of the atmosphere be on the increase, the plants and animals of low grounds would ascend to higher levels, the equatorial species would migrate into the temperate zone, and those of the temperate into the arctic circle.

But although some species might thus be preserved, every great change of climate must be fatal to many which can find no place of retreat when their original

habitations become unfit for them. For if the general temperature be on the rise, then there is no cooler region whither the polar species can take refuge; if it be on the decline, then the animals and plants previously established between the tropics have no resource. Suppose the general heat of the atmosphere to increase, so that even the arctic region became too warm for the musk-ox and rein-deer, it is clear that they must perish; so, if the torrid zone should lose so much of its heat by the progressive refrigeration of the earth's surface as to be an unfit habitation for apes, boas, bamboos, and palms, these tribes of animals and plants, or, at least, most of the species now belonging to them, would become extinct, for there would be no warmer latitudes for their reception.

It will follow, therefore, that as often as the climates of the globe are passing from the extreme of heat to that of cold — from the summer to the winter of the great year before alluded to* — the migratory movement will be directed constantly from the poles towards the equator; and for this reason the species inhabiting parallel latitudes, in the northern and southern hemispheres, must become widely different. For I assume on grounds before explained, that the original stock of each species is introduced into one spot of the earth only, and, consequently, no species can be at once indigenous in the arctic and antarctic circles.†

But when, on the contrary, a series of changes in the physical geography of the globe, or any other supposed cause, occasions an elevation of the general temperature, — when there is a passage from the winter to one of the vernal or summer seasons of the great

* Book I. chap. vii.

† Chap. viii.

cycle of climates,—then the order of the migratory movement is inverted. The different species of animals and plants direct their course from the equator towards the poles; and the northern and southern hemispheres may become peopled, to a great degree, by identical species. Such is not the actual state of the inhabited earth, as I have already shown in my sketch of the geographical distribution of its living productions; and this fact adds an additional proof to the geological evidence, derived from independent sources, that the general temperature has been cooling down during the epochs which immediately preceded our own.

I do not mean to speculate on the entire transposition of a group of animals and plants from tropical to polar latitudes, or the reverse, as a probable, or even possible, event; for although we may believe the mean annual temperature of one zone to be transferrible to another, we know that the same climate cannot be so transferred. Whatever be the general temperature of the earth's surface, comparative equability of heat will characterize the tropical regions; while great periodical variations will belong to the temperate, and still more to the polar, latitudes. These, and many other peculiarities connected with heat and light, depend on fixed astronomical causes, such as the motion of the earth and its position in relation to the sun, and not on those fluctuations of its surface, which may influence the general temperature.

Among many obstacles to such extensive transference of habitations we must not forget the immense lapse of time required, according to the hypothesis before suggested, to bring about a considerable change in climate. During a period so vast, the other causes of extirpation, before enumerated, would exert so

powerful an influence as to prevent all, save a very few hardy species, from passing from equatorial to polar regions, or from the tropics to the pole.*

But the power of accommodation to new circumstances is great in certain species, and might enable many to pass from one zone to another, if the mean annual heat of the atmosphere and the ocean were greatly altered. To the marine tribes, especially, such a passage would be possible; for they are less impeded in their migrations by barriers of land, than are the terrestrial by the ocean. Add to this, that the temperature of the ocean is much more uniform than that of the atmosphere investing the land; so that we may easily suppose that most of the testacea, fish, and other classes, might pass from the equatorial into the temperate regions, if the mean temperature of those regions were transposed, although a second expatriation of these species of tropical origin into the arctic and antarctic circles would probably be impossible.

On the principles above explained, if we found that at some former period, as when, for example, our carboniferous strata were deposited, the same tree-ferns and other plants inhabited the regions now occupied by Europe and Van Diemen's Land, we should suspect that the species in question had, at some antecedent period, inhabited lands within the tropics, and that an increase of the mean annual heat had caused them to emigrate into both the temperate zones. There are no geological data, however, as yet obtained, to warrant the opinion that such identity of species existed in the two hemispheres in the era in question.

Let us now consider more particularly the effect of

* See Book I. chap. vi. vii. and viii.

vicissitudes of climate in causing one species to give way before the increasing numbers of some other.

When temperature forms the barrier which arrests the progress of an animal or plant in a particular direction, the individuals are fewer and less vigorous as they approach the extreme confines of the geographical range of the species. But these stragglers are ready to multiply rapidly on the slightest increase or diminution of heat that may be favourable to them, just as particular insects increase during a hot summer, and certain plants and animals gain ground after a series of congenial seasons.

In almost every district, especially if it be mountainous, there are a variety of species the limits of whose habitations are conterminous, some being unable to proceed farther without encountering too much heat, others too much cold. Individuals, which are thus on the borders of the regions proper to their respective species, are like the outposts of hostile armies, ready to profit by every slight change of circumstances in their favour, and to advance upon the ground occupied by their neighbours and opponents.

The proximity of distinct climates, produced by the inequalities of the earth's surface, brings species possessing very different constitutions into such immediate contact, that their naturalizations are very speedy whenever opportunities of advancing present themselves. Many insects and plants, for example, are common to low plains within the arctic circle, and to lofty mountains in Scotland and other parts of Europe. If the climate, therefore, of the polar regions were transferred to our own latitudes, the species in question would immediately descend from these elevated stations to overrun the low grounds. Invasions of this

kind, attended by the expulsion of the pre-occupants, are almost instantaneous, because the change of temperature not only places the one species in a more favourable position, but renders the others sickly and almost incapable of defence.

These changes inconsistent with the theory of transmutation. — Lamarck, when speculating on the transmutation of species, supposed every modification in organization and instinct to be brought about slowly and insensibly in an indefinite lapse of ages. But he does not appear to have sufficiently considered how much every alteration in the physical condition of the habitable surface changes the relations of a great number of co-existing species, and that some of these would be ready instantly to avail themselves of the slightest change in their favour, and to multiply to the injury of others. Even if we thought it possible that the palm or the elephant, which now flourish in equatorial regions, could ever learn to bear the variable seasons of our temperate zone, or the rigours of an arctic winter, we might, with no less confidence, affirm, that they must perish before they had time to become habituated to such new circumstances. That they would be displaced by other species as often as the climate varied, may be inferred from the data before explained respecting the local extermination of species produced by the multiplication of others.

Suppose the climate of the highest part of the woody zone of Etna to be transferred to the sea-shore at the base of the mountain, no botanist would anticipate that the olive, lemon-tree, and prickly pear (*Cactus opuntia*), would be able to contend with the oak and chestnut, which would begin forthwith to descend to a lower level; or that these last would be able to stand their

ground against the pine, which would also, in the space of a few years, begin to occupy a lower position. We might form some kind of estimate of the time which might be required for the migrations of these plants; whereas we have no data for concluding that any number of thousands of years would be sufficient for one step in the pretended metamorphosis of one species into another, possessing distinct attributes and qualities.

This argument is applicable not merely to *climate*, but to any other cause of mutation. However slowly a lake may be converted into a marsh, or a marsh into a meadow, it is evident that before the lacustrine plants can acquire the power of living in marshes, or the marsh-plants of living in a less humid soil, other species, already existing in the region, and fitted for these several stations, will intrude and keep possession of the ground. So, if a tract of salt water becomes fresh by passing through every intermediate degree of brackishness, still the marine molluscs will never be permitted to be gradually metamorphosed into fluviatile species; because long before any such transformation can take place by slow and insensible degrees, other tribes, already formed to delight in brackish or fresh water, will avail themselves of the change in the fluid, and will, each in their turn, monopolize the space.

It is idle therefore to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature, which must always intervene and prevent the actual accomplishment of such conversions. A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which it previously inhabited, and where it has to contend

with a more vigorous species, is presented by the extirpation of savage tribes of men by the advancing colony of some civilized nation. In this case the contest is merely between two different *races* — two varieties, moreover, of a species which exceeds all others in its aptitude to accommodate its habits to the most extraordinary variations of circumstances. Yet few future events are more certain than the speedy extermination of the Indians of North America and the savages of New Holland in the course of a few centuries, when these tribes will be remembered only in poetry and tradition.

CHAPTER XI.

EXTINCTION AND CREATION OF SPECIES.

Theory of the successive extinction of species consistent with their limited geographical distribution — Opinions of botanists respecting the centres from which plants have been diffused — Whether there are grounds for inferring that the loss, from time to time, of certain animals and plants, is compensated by the introduction of new species? — Whether any evidence of such new creations could be expected within the historical era? (p. 169.) — The question whether the existing species have been created in succession must be decided by geological monuments.

Successive Extinction of Species consistent with their limited Geographical Distribution.

In the preceding chapters I have pointed out the strict dependence of each species of animal and plant on certain physical conditions in the state of the earth's surface, and on the number and attributes of other organic beings inhabiting the same region. I have also endeavoured to show that all these conditions are in a state of continual fluctuation, the igneous and aqueous agents remodelling, from time to time, the physical geography of the globe, and the migrations of species causing new relations to spring up successively between different organic beings. I have deduced as a corollary, that the species existing at any particular period must, in the course of ages, become

extinct one after the other. "They must die out," to borrow an emphatical expression from Buffon; "because Time fights against them."

If the views which I have taken are just, there will be no difficulty in explaining why the habitations of so many species are now restrained within exceedingly narrow limits. Every local revolution, such as those contemplated in the preceding chapter, tends to circumscribe the range of some species, while it enlarges that of others; and if we are led to infer that new species originate in one spot only, each must require time to diffuse itself over a wide area. It will follow, therefore, from the adoption of this hypothesis, that the recent origin of some species, and the high antiquity of others, are equally consistent with the general fact of their limited distribution, some being local, because they have not existed long enough to admit of their wide dissemination; others, because circumstances in the animate or inanimate world have occurred to restrict the range which they may once have obtained.

As considerable modifications in the relative levels of land and sea have taken place in certain regions since the existing species were in being, we can feel no surprize that the zoologist and botanist have hitherto found it difficult to refer the geographical distribution of species to any clear and determinate principles, since they have usually speculated on the phenomena, upon the assumption that the physical geography of the globe had undergone no material alteration since the introduction of the species now living. So long as this assumption was made, the facts relating to the geography of plants and animals appeared capricious in the extreme, and by many the subject was pro-

nounced to be so full of mystery and anomalies, that the establishment of a satisfactory theory was hopeless.

Centres from which plants have been diffused.—Some botanists conceived, in accordance with the hypothesis of Willdenow, that mountains were the centres of creation from which the plants now inhabiting large continents have radiated; to which De Candolle and others, with much reason, objected, that mountains, on the contrary, are often the barriers between two provinces of distinct vegetation. The geologist who is acquainted with the extensive modifications which the surface of the earth has undergone in very recent geological epochs, may be able, perhaps, to reconcile both these theories in their application to different regions.

A lofty range of mountains, which is so ancient as to date from a period when the species of animals and plants differed from those now living, will naturally form a barrier between contiguous provinces; but a chain which has been raised, in great part, within the epoch of existing species, and around which new lands have arisen from the sea within that period, will be a centre of peculiar vegetation.

"In France," observes De Candolle, "the Alps and Cevennes prevent a great number of the plants of the south from spreading themselves to the northward; but it has been remarked that some species have made their way through the gorges of these chains, and are found on their northern sides, principally in those places where they are lower and more interrupted."* Now the chains here alluded to have probably been of considerable height ever since the era when the existing vegetation began to appear, and were it not for

* Essai Elémentaire, &c. p. 46.

the deep fissures which divide them, they might have caused much more abrupt terminations to the extension of distinct assemblages of species.

Parts of the Italian peninsula, on the other hand have gained a considerable portion of their present height, since a majority of the marine species now inhabiting the Mediterranean, and probably, also, since the terrestrial plants of the same region, were in being. Large tracts of land have been added, both on the Adriatic and Mediterranean side, to what originally constituted a much narrower range of mountains, if not a chain of islands running nearly north and south, like Corsica and Sardinia. It may therefore be presumed that the Apennines have been a centre whence species have diffused themselves over the contiguous *lower* and *newer* regions. In this and all analogous situations, the doctrine of Willdenow, that species have radiated from the mountains as from centres, may be well founded.

Introduction of New Species.

If the reader should infer, from the facts laid before him in the preceding chapters, that the successive extinction of animals and plants may be part of the constant and regular course of nature, he will naturally inquire whether there are any means provided for the repair of these losses? Is it part of the economy of our system that the habitable globe should, to a certain extent, become depopulated both in the ocean and on the land; or that the variety of species should diminish until some new era arrives when a new and extraordinary effort of creative energy is to be displayed? Or is it possible that new species can be called into

being from time to time, and yet that so astonishing a phenomenon can escape the observation of naturalists?

Humboldt has characterized these subjects as among the mysteries which natural science cannot reach; and he observes that the investigation of the origin of beings does not belong to zoological or botanical geography. To geology, however, these topics do strictly appertain; and this science is chiefly interested in inquiries into the state of the animate creation as it now exists, with a view of pointing out its relations to antecedent periods when its condition was different.

Before offering any hypothesis towards the solution of so difficult a problem, let us consider what kind of evidence we ought to expect, in the present state of science, of the first appearance of new animals or plants, if we could imagine the successive creation of species to constitute, like their gradual extinction, a regular part of the economy of nature.

In the first place, it is obviously more easy to prove that a species, once numerously represented in a given district, has ceased to be, than that some other which did not pre-exist has made its appearance — assuming always, for reasons before stated, that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once.

So imperfect has the science of natural history remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old continent, long inhabited by the most civilized nations.

Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult, even in contemplation, to anticipate the time when we shall be entitled to make any other hypothesis in regard to all the marine tribes, and to by far the greater number of the terrestrial; — such as birds, which possess such unlimited powers of migration; insects which, besides their numbers, are also so capable of being diffused to vast distances; and cryptogamous plants, to which, as to many other classes, both of the animal and vegetable kingdom, similar observations are applicable.

What kind of evidence of new creations could be expected? — What kind of proofs, therefore, could we reasonably expect to find of the origin at a particular period of a new species?

Perhaps it may be said in reply that, within the last two or three centuries, some forest tree or new quadruped might have been observed to appear suddenly in those parts of England or France which had been most thoroughly investigated; — that naturalists might have been able to show that no such living being inhabited any other region of the globe, and that there was no tradition of any thing similar having before been observed in the district where it had made its appearance.

Now, although this objection may seem plausible, yet its force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such con-

spicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our observation. There are perhaps more than a million species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe. The terrestrial plants may amount, says De Candolle, to somewhere between 110,000 and 120,000 *; but the data on which this conjecture is founded are considered by many botanists to be vague and unsatisfactory. Sprengel only enumerated, in 1827, about 31,000 known phænogamous, and 6000 cryptogamous plants; but that naturalist omitted many, perhaps 7000 phænogamous, and 1000 cryptogamous species. Mr. Lindley is of opinion that it would be rash, in the present state of science, to speculate on the existence of more than 80,000 phænogamous, and 10,000 cryptogamous plants. "If we take," he says, in a letter to the author on this subject, "37,000 as the number of published phænogamous species, and then add, for the undiscovered species in Asia and New Holland 15,000, in Africa 10,000, and in America 18,000, we have 80,000 species; and if 7000 be the number of published cryptogamous plants, and we allow 3000 for the undiscovered species (making 10,000), there would then be, on the whole, 90,000 species."

It was supposed by Linnæus that there were four or five species of insects in the world for each phænogamous plant: but if we may judge from the relative proportion of the two classes in Great Britain, the number of insects must be still greater; for the total

* Géog. des Plantes. Dict. des Sci.

number of British insects, "according to the last census," is about 12,500 *, whereas there are only 1500 phænogamous plants indigenous to our island. As the insects are much more numerous in hot countries than in our temperate latitudes, it seems difficult to avoid the conclusion that there are more than half a million species in the world.

The number of known mammifers, according to Temminck, exceeds 800, and Baron Cuvier estimated the amount of known fishes at 6000. Nearly 6000 species of birds have likewise been ascertained.† We have still to add the reptiles, and all the invertebrated animals, exclusive of insects. It remains, in a great degree, mere matter of conjecture what proportion the aquatic tribes may bear to the denizens of the land; but the habitable surface beneath the waters can hardly be estimated at less than double that of the continents and islands, even admitting that a very considerable area is destitute of life, in consequence of great depth, cold, darkness, and other circumstances. In the late polar expedition it was found that, in some regions, as in Baffin's Bay, there were marine animals inhabiting the bottom at great depths, where the temperature of the water was below the freezing point. That there is life at much greater profundities in warmer regions, may be confidently inferred. I have before stated that marine plants not only exist, but acquire vivid colours at depths where, to our senses, there would be darkness deep as night.

The ocean teems with life—the class of *polyps* alone are conjectured by Lamarck to be as strong in indivi-

* See Catalogue of Brit. Insects, by John Curtis, Esq.

† See Quarterly Review, No. xciv. p. 337.

duals as insects. Every tropical reef is described as covered with corals and sponges, and swarming with crustacea, echini, and testacea; while almost every tide-washed rock in the world is carpeted with fuci and supports some corallines, actiniæ, and mollusca. There are innumerable forms in the seas of the warmer zones, which have scarcely begun to attract the attention of the naturalist; and there are parasitic animals without number, three or four of which are sometimes appropriated to one genus, as to the *Balæna*, for example. Even though we concede, therefore, that the geographical range of marine species is more extensive in general than that of the terrestrial (the temperature of the sea being more uniform, and the land impeding less the migrations of the oceanic than the ocean those of the terrestrial species), yet it seems probable that the aquatic tribes far exceed in number the inhabitants of the land.

Without insisting on this point, it may be safe to assume, that, exclusive of microscopic beings, there are between one and two millions of species now inhabiting the terraqueous globe; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, much more than a million of years might be required to bring about a complete revolution in organic life.

I am not hazarding at present any hypothesis as to the probable rate of change; but none will deny that, when the *annual* birth and the *annual* death of one species on the globe is proposed as a mere speculation, this at least is to imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water

about equal in dimensions to Europe, and might contain a twentieth part of the million of species which may be assumed to exist in the animal kingdom. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century. But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we must exclude them from our consideration; and if they constitute half of the entire number, then one species only might be lost in forty years among the terrestrial tribes. Now the mammalia, whether terrestrial or aquatic, bear so small a proportion to other classes of animals, forming less, perhaps, than one thousandth part of the whole, that, if the longevity of species in the different orders were equal, a vast period must elapse before it would come to the turn of this conspicuous class to lose one of their number. If one species only of the whole animal kingdom died out in forty years, no more than one mammifer might disappear in 40,000 years, in a region of the dimensions of Europe.

It is easy, therefore, to see, that, in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world.

The observations of naturalists, upon living species, may, in the course of future centuries, accumulate positive data, from which an insight into the laws

which govern this part of our terrestrial system may be derived; but, in the present deficiency of historical records, we have traced up the subject to that point where geological monuments alone are capable of leading us on to the discovery of ulterior truths. To these, therefore, we must now appeal, carefully examining the strata of recent formation wherein the remains of *living* species, both animal and vegetable, are known to occur. We must study these strata in strict reference to their chronological order, as deduced from their superposition, and other relations. From these sources we may learn which of the species, now our contemporaries, have survived the greatest revolutions of the earth's surface; which of them have co-existed with the greatest number of animals and plants now extinct, and which have made their appearance only when the animate world had nearly attained its present condition.

From such data we may be enabled to infer, whether species have been called into existence in succession, or all at one period; whether singly, or by groups simultaneously; whether the antiquity of man be as high as that of any of the inferior beings which now share the planet with him, or whether the human species is one of the most recent of the whole.

To some of these questions we can even now return a satisfactory answer; and with regard to the rest, we have some data to guide conjecture, and to enable us to speculate with advantage: but it would be premature to anticipate such discussions until I have laid before the reader an ample body of materials amassed by the industry of modern geologists.

CHAPTER XII.

EFFECTS PRODUCED BY THE POWERS OF VITALITY ON THE STATE OF THE EARTH'S SURFACE.

Modifications in physical geography caused by organic beings — Why the vegetable soil does not augment in thickness — The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water, untenable (p. 180.) — Conservative influence of vegetation (p.184.)—Rain diminished by felling of forests — Distribution of American forests dependent on direction of predominant winds (p. 188.) — Influence of man in modifying the physical geography of the globe.

The second branch of our inquiry, respecting changes of the organic world, relates to the processes by which the remains of animals and plants become fossil, or, to speak still more generally, to all the effects produced by the powers of vitality on the surface and shell of the earth.

Before entering on the principal division of this subject, the imbedding and preservation of animal and vegetable remains, I shall offer a few remarks on the superficial modifications caused directly by the agency of organic beings, as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

In considering alterations of this kind, brought about in the physical geography of particular tracts, we are too apt to think exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings, we are familiar. Here the direct power of animals and plants to cause any important variation is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and, instead of contemplating the dry land, consider that larger portion which is assigned to the aquatic tribes, we discover the great influence of the living creation, in imparting varieties of conformation to the solid exterior which the agency of inanimate causes alone could not produce.

Thus, when timber is floated into the sea, it is often drifted to vast distances, and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs; it is probable that almost all the matter of which they are composed is supplied by mineral springs, which often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions hundreds of leagues in extent. The matter thus constantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest and secrete the carbonate of lime on the summits of submarine mountains, and form

reefs many hundred feet in thickness, and hundreds of miles in length, where, but for them, none might ever have existed.

Why the vegetable soil does not augment in thickness. — If no such voluminous masses are formed on the land, it is not from the want of solid matter in the structure of terrestrial animals and plants; but merely because, as I have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place — where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there during the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials, therefore, might constitute a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea. The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported.

The decomposition of the strata themselves, especially of their alkaline ingredients and of the organic remains which they so frequently include, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest

parts of animals and plants which die and putrefy in the air, where they are soon resolved into the elements of which they are composed; and while a portion of these constituents is volatilized, the rest is taken up by rain water, and sinks into the earth, or flows towards the sea; so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen; so that water and the atmosphere contain all of them, either in their own composition or in solution.* The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean, and to circulate round the globe.

It is well known that, when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they soon become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air of the atmosphere, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil,

* See some good remarks on the Formation of Soils, Bakewell's Geology, chap. xviii.

he observes, consists partly of loose earthy materials, easily removed, in the form of sand and gravel; partly of finer particles, suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. "The soil," he supposes, "although continually diminished from this cause, remains the same in quantity, or at least nearly the same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks." *

That the repair of the *earthy* portion of the soil can proceed, as Playfair suggests, only from the decomposition of rocks, may be admitted; but the *vegetable* matter may be supplied, and is actually furnished, in a great degree, by absorption from the atmosphere; so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

If the quantity of food consumed by terrestrial animals, and the elements imbibed by the roots and leaves of plants, were derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single

* Illust. of Hutt. Theory, § 103.

particle by the action of organic beings; and this conclusion is not far from the truth; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down, every century, into the sea; and, together with forests of drift-timber, are imbedded in subaqueous deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

On the other hand, fresh supplies are derived by the atmosphere, and by running water, as before stated, from the disintegration of rocks and their organic contents, and through the agency of mineral springs from the interior of the earth, from whence all the elements before mentioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found, by Dr. Daubeny, to be contained very generally in the waters of mineral springs.

Vegetation not an antagonist power counterbalancing the action of running water.—If we suppose that the copious supply from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we concede the utmost that is consistent with probability. An opinion, however, has been expressed, that the processes of vegetable life, by absorbing various gases from the atmosphere, cause so large a mass of solid

matter to accumulate on the surface of the land, that this mass alone may constitute a great counterpoise to all the matter transported to lower levels by the aqueous agents of decay. Torrents and rivers, it is said—the waves of the sea and marine currents—act upon lines only; but the power of vegetation to absorb the elastic and non-elastic fluids circulating round the earth, extends over the whole surface of the continents. By the silent but universal action of this great antagonist power, the spoliation and waste caused by running water on the land, and by the movements of the ocean, are neutralized, and even counterbalanced.*

In opposition to these views, I conceive that we shall form a juster estimate of the influence of vegetation if we consider it as being in a slight degree conservative, and capable of retarding the waste of land, but not of acting as an antagonist power. The vegetable mould is seldom more than a few feet in thickness, and frequently does not exceed a few inches; and we by no means find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where, consequently, there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs. On the contrary, these higher and older regions are more frequently denuded, so as to expose the bare rock to the action of the sun and air.

We find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of

* See Professor Sedgwick's Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

matter due to their agency are by no means the most conspicuous. Indeed it is in these latitudes, where the vegetation is most active, that, for reasons to be explained in the next chapter, even those superficial peat mosses are unknown which cover a large area in some parts of our temperate zone. If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually into the sea, the effects would long ere this have constituted one of the most striking features in the structure and composition of our continents. All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of earthy sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist has not, in every instance, a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. In that case the turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within; and when that skin bursts, as has often happened in Ireland, and many parts of the Continent, a violent inundation ensues. Examples will be mentioned in a subsequent chapter, where the muddy torrent has hollowed out ravines, and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat.

I may explain more clearly the kind of force which

I imagine vegetation to exert, by comparing it to the action of frost, which augments the height of some few alpine summits, by causing masses of perpetual snow to accumulate upon them, or fills up some valleys with glaciers; but although by this process of congelation the rain-water that has risen by evaporation from the sea is retained for a while in a solid form upon the land, and though some elevated spots may be protected from waste by a constant covering of ice, yet, on the other hand, the sudden melting of snow often accelerates the degradation of rock. Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase; the one melts, the other putrefies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life.

I have already stated that, in the known operation of the *igneous* causes, a real antagonist power is found, which may counterbalance the levelling action of running water * ; and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the ejection of matter by volcanos, may not be fully adequate to restore that inequality of the surface which rivers and the waves and currents of the ocean annually tend to lessen. If a counterpoise be derived from this source, the quantity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the surface of the earth more nearly to a state of equilibrium than that which it has now attained; and, on the other hand, the force of the

* Vol. I. p. 255. ; Vol. II. p. 398.

aqueous agents themselves might thus continue for ever unimpaired. This permanence of the average intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned; provided only that indefinite periods of time are contemplated.

As to the intensity of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient convulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But, notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time is in its infancy; and there can be no doubt that great partial alterations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Conservative influence of vegetation.—If, then, vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative,—how far it may retard the levelling effects of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river, and may prevent hills of loose sand from being blown away by the wind; for the roots bind together the

separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually, instead of flowing off in a mass and with great velocity. The old Italian hydrographers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausentinium of the Romans) was denuded, and immediately the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil.*

This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rain-water and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain, and undermining the cliffs on each side of every valley, the height of the intervening rising grounds may remain stationary.

* Treatise on Rivers and Torrents, p. 5. Garston's translation.

In this manner, a cone of loose scoriæ, sand, and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any further dilapidation ; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer, from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated, since their formation; but the atmospheric action alone, in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a tour in Spain, in 1830, I was surprised to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage; while the roots of the pines, holm oaks, and some other trees, were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Oristo and Vich, and near San Lorenzo. But, being overtaken by a violent thunder-storm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained; and I was taught that, in speculating on the greater effects which the direct action of rain may once have produced on the surface of certain parts of England, we need not revert to periods when the heat of the climate was *tropical*.

In the torrid zone the degradation of land is generally

more rapid; but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall, the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction, so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains; which, when they have thus been broken in their fall, are quickly absorbed by the ground beneath, or, when thrown into the drainage depressions give rise to furious torrents.*

Influence of Man in modifying the Physical Geography of the Globe.

Before concluding this chapter, I shall offer a few observations on the influence of man in modifying the physical geography of the globe; for we must class his agency among the powers of organic nature.

Felling of forests. — The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica.† For in tropical countries, where the quantity of aqueous vapour in the atmosphere is great, but where, on the other hand, the direct rays of the sun are most powerful, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a source

* De la Beche, Geol. Man., p. 184. first ed.

† Phil. Trans., vol. ii. p. 294.

of humidity; and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves, moreover, of all plants are alembics, and some of those in the torrid zone have the remarkable property of distilling water, thus contributing to prevent the earth from becoming parched up.

Distribution of the American forests.—There can be no doubt, then, that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation re-acts upon the climate; but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject "that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean," seems far more rational. In all countries, he says, "having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees; because, after the surface is saturated with water, the rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a

greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours."*

"In all regions," he continues, "where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry; and hence parched deserts will generally be found on the west side of countries within the trópics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is precipitated in part upon the mountains of Brazil, which are but low, and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, is at length arrested by the Andes, where it falls down in showers on their summits. The aërial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in India, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side, while on the other the weather remains clear and dry. The rains in this case change regularly from the west side to the east, and vice versâ, *with the monsoons.* But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture

* Maclaren, art. America, Encyc. Britannica.

brought by the prevailing winds from the Pacific Ocean: rains are copious on their summits, and in Chili on their *western* declivities; but none falls on the plains to the *eastward*, except occasionally when the wind blows from the Atlantic."*

I have been more particular in explaining these views, because they appear to place in a true light the dependence of vegetation on climate, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

It has been affirmed, that formerly, when France and England were covered with wood, Europe was much colder than at present; that the winters in Italy were longer, and that the Seine, and many other rivers, froze more regularly every winter than now. M. Arago, in a recent essay on this subject, has endeavoured to show, by tables of observations on the congelation of the Rhine, Danube, Rhone, Po, Seine, and other rivers, at different periods, that there is no reason to believe the cold to have been in general more intense in ancient times.† He admits, however, that the climate of Tuscany has been so far modified, by the removal of wood, as that the winters are less cold; but the summers also, he contends, are less hot than of old; and the summers, according to him, were formerly hotter in France than in our own times. His evidence is derived chiefly from documents showing that wine was made three centuries ago in the Vivarais and several other provinces, at an earlier

* Maclaren, art. America, Encyc. Britannica, where the position of the American forests, in accordance with this theory, is laid down in a map.

† Annuaire par le Bureau des Long. 1834.

season, at greater elevations, and in higher latitudes than are now found suitable to the vine.

In the United States of North America it is unquestionable that the rapid *clearing* of the country has rendered the winters less severe and the summers less hot; in other words, the extreme temperature of January and July have been observed from year to year to approach nearer to each other. Whether in this case, or in France, the *mean* temperature has been raised, seems by no means as yet decided; but there is no doubt that the climate has become, as Buffon would have said, "less excessive."

The modifications of the surface, resulting from human agency, are only great when we have obtained so much knowledge of the working of the laws of nature as to be enabled to use them as powerful instruments to effect our purposes. We command nature, according to the saying of the philosopher, by obeying her laws; and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to reconvey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. Yet they have been able to vary the distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread by annual inundations over the plains.

I have explained how the form of the delta of the

Po has been altered by this system of embankment, and how much more rapid have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit, however, to these modifications, since the danger of floods augments with the increasing height of the river-beds, while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country. "In the Ganges," says Major R. H. Colebrooke, "no sooner is a slight covering of soil observed on a new sand-bank than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year; and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, the natives take possession, and bring over their families, cattle, and effects. They choose the highest spots for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for, although the foundation is sandy, the uppermost soil, being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject."*

If Bengal were inhabited by a nation more advanced

* Asiatic Trans., vol. vii.

in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods; but no human power could ever prevent the Ganges or the Mississippi from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted whether any system could be devised so conducive to *national* wealth as the simple plan pursued by the peasants of Hindostan, who, wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist the Gangetic islands and their migratory colonies may present an epitome of the globe as tenanted by man; for during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which subterranean causes have upheaved from the deep. Whether the human species will outlast the whole or a great part of the continents and islands now seen above the waters, is a question far beyond the reach of our conjectures; but thus much may be inferred from geological data, — that if such should be its fate, it will be no more than has already been the lot of pre-existing species, some of which have, ere now,

outlived the form and distribution of land and sea which prevailed at the era of their birth.*

I have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents.† If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries.‡ But, in the mean time, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town, projecting as a narrow promontory, must have become exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which man can obtain over the igneous agents is less even than that which he may exert over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of volcanic eruptions; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect is occasionally to divert the course of a lava-stream, and to prevent the burning matter, for a season, from overwhelming a city, or some other of the proudest works of human industry.

* See book iv. chap. ix. † Book ii. chap. vii. ‡ Vol. II. p. 31.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult to find any thing analogous in the agency of inferior beings; for we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider the powers of all other animated agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species; a topic on which I have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of vegetation, and such may often have been the result of the appearance of new species upon the earth. The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

It would be rash, however, to pretend to decide how far the power of man to modify the surface may differ in kind or degree from that of other living beings; the problem is certainly more complex than

many who have speculated on such topics have imagined. If land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the new tract would become covered with vegetation. The change next in importance would seem to be when animals first enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that *a single species*, in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. In mining operations he conveys upwards a certain quantity of materials from the bowels of the earth; but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards thrown into the sea, and by this means, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the

abrading force of rain, and diminish the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical agents, whether aqueous or igneous, of the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanos in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption.*

* Vol. I. p. 367.

CHAPTER XIII.

INCLOSING OF FOSSILS IN PEAT, BLOWN SAND, AND VOLCANIC EJECTIONS.

Division of the subject — Imbedding of organic remains in deposits on emerged land — Growth of peat — Site of ancient forests in Europe now occupied by peat—Bog iron-ore (p. 204.) Preservation of animal substances in peat — Miring of quadrupeds — Bursting of the Solway moss — Imbedding of organic bodies and human remains in blown sand (p. 210.) — Moving sands of African deserts — De Luc on their recent origin — Buried temple of Ipsambul — Dried carcasses in the sands — Towns overwhelmed by sand-floods — Imbedding of organic and other remains in volcanic formations on the land.

Division of the subject. — The next subject of inquiry is the mode in which the remains of animals and plants become fossil, or are buried in the earth by natural causes. M. Constant Prevost has observed, that the effects of geological causes are divisible into two great classes; those produced on the surface during the submersion of land beneath the waters, and those which take place after its emersion. Agreeably to this classification, I shall consider, first, in what manner animal and vegetable remains become included and preserved in deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of seas or lakes; secondly, the manner in which organic remains become imbedded in subaqueous deposits.

Under the first division, I shall treat of the following topics: — 1st, the growth of peat, and the preservation of vegetable and animal remains therein; — 2dly, the burying of organic remains in blown sand; — 3dly, of the same in the ejections and alluviums of volcanos; — 4thly, in alluviums generally, and in the ruins of landslips; — 5thly, in the mud and stalagmite of caves and fissures.

Growth of Peat, and Preservation of Vegetable and Animal Remains therein.

The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrefying. It may consist of any of the numerous plants which are capable of growing in such *stations;* but a species of moss (*Sphagnum palustre*) constitutes a considerable part of the peat found in marshes of the north of Europe; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying.* Reeds, rushes, and other aquatic plants may usually be traced in peat; and their organization is often so entire that there is no difficulty in discriminating the distinct species.

Analysis of peat. — In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire; and the residuum consists of earths usually of the same kind as the substratum of clay, marl, gravel, or rock,

* For a catalogue of the plants which contribute to the generation of peat, see Dr. Rennie on Peat, pp. 171—178.; and Dr. Macculloch's Western Isles, vol. i. p. 129.

on which they are found, together with oxide of iron. "The peat of the chalk counties of England," observes the same writer, "contains much gypsum; but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter."* From the researches of Dr. Macculloch, it appears that peat is intermediate between simple vegetable matter and lignite, the conversion of peat to lignite being gradual, and being brought about by the prolonged action of water.†

Peat abundant in cold and humid climates. — Peat is sometimes formed on a declivity in mountainous regions, where there is much moisture; but in such situations it rarely, if ever, exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick, and upwards; but in such cases it generally owes one half of its volume to the water which it contains. It has seldom, if ever, been discovered within the tropics; and it rarely occurs in the valleys, even in the south of France and Spain. It abounds more and more, in proportion as we advance farther from the equator, and becomes not only more frequent but more inflammable in northern latitudes.‡

Extent of surface covered by peat. — There is a vast extent of surface in Europe covered with peat, which, in Ireland, is said to extend over a tenth of the whole island. One of the mosses on the Shannon is described by Dr. Boate to be fifty miles long, by two or three broad; and the great marsh of Montoire, near the

* Irish Bog Reports, p. 209.
† System of Geology, vol. ii. p. 353.
‡ Rev. Dr. Rennie on Peat, p. 260.

mouth of the Loire, is mentioned, by Blavier, as being more than fifty leagues in circumference. It is a curious and well-ascertained fact, that many of these mosses of the north of Europe occupy the place of forests of pine and oak, which have, many of them, disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects, or by putrefaction; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes originating in this source. Thus, in Mar forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immured in peat, formed partly out of their perishing leaves and branches, and in part from the growth of other plants. We also learn, that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat moss near Lochbroom, in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat.* Dr. Walker mentions a similar change, when, in the year 1756, the whole wood of Drumlanrig in Dumfries-shire, was overset by the wind. Such events explain the occurrence, both in Britain and on the Continent, of mosses where the trees are all broken within two or three feet of the original surface, and where their trunks all lie in the same direction.†

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as

* Dr. Rennie's Essays, p. 65. † Ibid., p. 30.

also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the sub-soil, that no doubt can be entertained of their having generally grown on the spot. They consist, for the most part, of the fir, the oak, and the birch: where the sub-soil is clay, the remains of oak are the most abundant; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has, moreover, been observed, that in Scotland, as also in many parts of the Continent, the largest trees are found in those peat-mosses which lie in the least elevated regions, and that the trees are proportionally smaller in those which lie at higher levels; from which fact De Luc and Walker have both inferred, that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves also, and fruits of each species, are continually found immersed in the moss along with the parent trees; as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Recent origin of some peat-mosses.—In Hatfield moss, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found ninety feet long, and sold for masts and keels of ships; oaks have also been discovered there above one hun-

dred feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions, No. 275., which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of Kincardine, and several others, Roman roads have been found covered to the depth of eight feet by peat. All the coins, axes, arms, and other utensils found in British and French mosses, are also Roman; so that a considerable portion of the European peat-bogs are evidently not more ancient than the age of Julius Cæsar. Nor can any vestiges of the ancient forests described by that general, along the line of the great Roman way in Britain, be discovered, except in the ruined trunks of trees in peat.

De Luc ascertained that the very site of the aboriginal forests of Hircinia, Semana, Ardennes, and several others, are now occupied by mosses and fens; and a great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. Several of the British forests, however, which are now mosses, were cut at different periods, by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut and burnt, in the reign of Edward I.; as were many of those in Ireland, by Henry II., to prevent the natives from harbouring in them, and harassing his troops.

It is curious to reflect that considerable tracts have, by these accidents, been permanently sterilized, and that during a period when civilization has been making great progress, large areas in Europe have, by human agency, been rendered less capable of administering

to the wants of man. Rennie observes, with truth, that in those regions alone which the Roman eagle never reached—in the remote circles of the German empire, in Poland and Prussia, and still more in Norway, Sweden, and the vast empire of Russia—can we see what Europe was before it yielded to the power of Rome.* Desolation now reigns where stately forests of pine and oak once flourished, such as might now have supplied all the navies of Europe with timber.

Sources of bog iron-ore.—At the bottom of peat-mosses there is sometimes found a cake, or "pan," as it is termed, of oxide of iron, and the frequency of bog iron-ore is familiar to the mineralogist. The oak, which is so often found dyed black in peat, owes its colour to the same metal. From what source the iron is derived is by no means obvious, since we cannot in all cases suppose that it has been precipitated from the waters of mineral springs. According to Fourcroy there is iron in all compact wood, and it is the cause of one-twelfth part of the weight of oak. The heaths (*Ericæ*) which flourish in a sandy ferruginous soil, are said to contain more iron than any other vegetable.

It has been suggested that iron, being soluble in acids, may be diffused through the whole mass of vegetables, when they decay in a bog, and may, by its superior specific gravity, sink to the bottom, and be there precipitated, so as to form bog iron-ore; or where there is a sub-soil of sand or gravel, it may cement them into ironstone or ferruginous conglomerate.†

Preservation of animal substances in peat.—One interesting circumstance attending the history of peat-

* Essays, &c., p. 74. † Ibid., p. 347.

mosses is the high state of preservation of animal substances buried in them for periods of many years. In June, 1747, the body of a woman was found six feet deep, in a peat-moor in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages; yet her nails, hair, and skin, are described as having shown hardly any marks of decay. On the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was fresh and unimpared.* In the Philosophical Transactions, we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; "the colour of their skin was fair and natural, their flesh soft as that of persons newly dead."†

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous

* Dr. Rennie, Essays, &c., p. 521., where several other instances are referred to.

† Phil. Trans., vol. xxxviii., 1734.

and tasteless substance; but which, when exposed to heat, emitted an odour precisely similar to broiled bacon.*

Cause of the antiseptic property of peat.—We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way.†

The tannin occasionally present in peat is the produce, says Dr. Macculloch, of tormentilla, and some other plants; but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocire by the action of water merely; an explanation which appears clearly applicable to some of the cases above enumerated. ‡

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud, underlying a turfy surface, upon which they have rashly ventured, or, at other times, a bog "bursts," in the manner before

* Dr. Rennie, Essays, &c., p. 521. † Ibid., p. 531.
‡ Syst. of Geol., vol. ii. pp. 340—346.

described, and animals may be involved in the peaty alluvium.*

In the extensive bogs of Newfoundland cattle are sometimes found buried with their heads only and neck above ground; and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on the "quaking moss" are often mired, or "laired," as it is termed; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible.†

Solway moss. — The description given of the Solway moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semifluid. The adventurous passenger, therefore, who sometimes in dry seasons traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

"At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional,

* See above, p. 182.

† Phil. Trans., vol. xv. p. 949.

but it is now authenticated; a man and horse, in complete armour, having been found by peat-diggers, in the place where it was always supposed the affair had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished."*

This same moss, on the 16th of December, 1772, having been filled with water during heavy rains, rose to an unusual height, and then burst. A stream of black half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about twenty-five feet; and the height of the moss, on the lowest parts of the country which it invaded, was at least fifteen feet.

Bursting of a peat-moss in Ireland.— A recent inundation in Sligo (January, 1831) affords another example of this phenomenon. After a sudden thaw of snow the bog between Bloomfield and Geevah gave way; and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream, and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

Bones of herbivorous quadrupeds in peat.— The

* Observations on Picturesque Beauty, &c., 1772.

antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed; for portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also, occur; and in Ireland and the Isle of Man skeletons of a gigantic elk. M. Morren has discovered in the peat of Flanders, the bones of otters and beavers *; but no remains have been met with belonging to those extinct quadrupeds of which the living congeners inhabit warmer latitudes, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, though these are so common in superficial deposits of silt, mud, sand, or stalactite, in various districts throughout Great Britain. Their absence seems to imply that they had ceased to live before the atmosphere of this part of the world acquired that cold and humid character which favours the growth of peat.

Remains of ships, &c., in peat-mosses. — From the facts before mentioned, that mosses occasionally burst, and descend in a fluid state to lower levels, it will readily be seen that lakes and arms of the sea may occasionally become the receptacles of drift-peat. Of this, accordingly, there are numerous examples; and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses; and Gerard, in his History of the Valley of the Somme, mentions that in the lowest tier of that

* Bulletin de la Soc. Géol. de France, tom. ii. p. 26.

moss was found a boat loaded with bricks, proving that these mosses were at one period navigable lakes and arms of the sea, as were also many mosses on the coast of Picardy, Zealand, and Friesland, from which soda and salt are procured.* The canoes, stone hatchets, and stone arrow-heads, found in peat in different parts of Great Britain, lead to similar conclusions.

Imbedding of Human and other Remains and Works of Art in Blown Sand.

The drifting of sand may next be considered among the causes capable of preserving organic remains and works of art on the emerged land.

African sands.—The sands of the African deserts have been driven by the west winds over all the lands capable of tillage on the western banks of the Nile, except such as are sheltered by mountains.† And thus the ruins of ancient cities have been buried between the Temple of Jupiter Ammon and Nubia. M. G. A. de Luc attempted to infer the recent origin of our continents, from the fact that these moving sands have arrived only in modern times at the fertile plains of the Nile. The same scourge, he said, would have afflicted Egypt for ages anterior to the times of history, had the continents risen above the level of the sea several hundred centuries before our era.‡ But the author proceeded in this, as in all his other chronological computations, on a multitude of gratuitous assumptions. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period;

* Dr. Rennie, Essays on Peat-Moss, p. 205.

† M. G. A. de Luc, Mercure de France, Sept. 1809. ‡ Ibid.

for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand flood might have been long posterior to the laying dry of the greater portion of that continent. That the different parts of Europe were not all elevated at one time is now generally admitted. De Luc should also have pointed out the depth of drift sand in various parts of the great Libyan deserts, and have shown whether any valleys of large dimensions had been filled up — how long these may have arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history.

No mode of interment can be conceived more favourable to the conservation of monuments for indefinite periods than that now so common in the region immediately westward of the Nile. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust.*

At some future period, perhaps, when the pyramids shall have perished, the action of the sea, or an earthquake, may lay open to the day some of these buried temples. Or we may suppose the desert to remain undisturbed, and changes in the surrounding sea and

* Stratton, Ed. Phil. Journ., No. V. p. 62.

land to modify the climate and the direction of the prevailing winds, so that these may then waft away the Libyan sands as gradually as they once brought them to those regions. Thus, many a town and temple of higher antiquity than Thebes or Memphis may re-appear in their original integrity, and a part of the gloom which overhangs the history of the earlier nations be dispelled.

Whole caravans are said to have been overwhelmed by the Libyan sands; and Burckhardt informs us that "after passing the Akaba, near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sand." — "We did not see," says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, "the least appearance of vegetation; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently expired animals I could not perceive the slightest offensive smell; and in those long dead, the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places; for, in a short time, a slight mound is formed round them, and they become stationary."*

Towns overwhelmed by sand floods. — The burying of several towns and villages in England and France by blown sand is on record; thus, for example, near

* Travels in North Africa in the Years 1818, 1819, and 1820, p. 83.

St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that nothing was seen but the spire of the church.*

In Suffolk, in the year 1688, part of Downham was overwhelmed by sands which had broken loose about 100 years before, from a warren five miles to the south-west. This sand had, in the course of a century, travelled five miles, and covered more than 1000 acres of land.† A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells, in which some terrestrial shells are inclosed entire. By the shifting of these sands the ruins of ancient buildings have been discovered; and in some cases where wells have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some places, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand.‡

Imbedding of Organic and other Remains in Volcanic Formations on the Land.

I have in some degree anticipated the subject of this section in a former volume, when speaking of the buried cities around Naples, and those on the flanks of

* Mém. de l'Acad. des Sci. de Paris, 1772. — Malte-Brun's Geol. vol. i. p. 425.

† Phil. Trans., vol. ii. p. 722.

‡ Boase on Submersion of Part of the Mount's Bay, &c., Trans. Roy. Geol. Soc. of Cornwall, vol. ii. p. 140.

Etna.* From the facts referred to, it appeared that the preservation of human remains and works of art is frequently due to the descent of floods caused by the copious rains which accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity; and in 1822 surprised and suffocated, as was stated, seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those, formed after the eruption of Vesuvius in 1822, are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava current. After consolidation, the lava affords secure protection to the lighter and more removeable mass below, in which the organic relics may be enveloped. The Herculanean tuffs containing the rolls of Papyrus, of which the characters are still legible, have, as was before remarked, been for ages covered by lava.

Another mode by which lava may tend to the conservation of imbedded remains, at least of works of human art, is by its overflowing them when it is not intensely heated, in which case they sometimes suffer little or no injury.

* Vol. II. pp. 147—172.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down a great number of statues and other articles in the vaults of Catania; and at the depth of thirty-five feet in the same current, on the site of Mompiliere, one of the buried towns, the bell of a church and some statues were found uninjured.*

There are several buried cities in Central India, which might probably yield a richer harvest to the antiquary than Pompeii and Herculaneum.† The city of Oujein (or Oojain) was, about fifty years before the Christian era, the seat of empire, of art, and of learning; but in the time of the Rajah Vicramaditya, it was overwhelmed, together, as tradition reports, with more than eighty other large towns in the provinces of Malwa and Bagur, "by a shower of earth." The city which now bears the name is situated a mile to the southward of the ancient town. On digging on the spot where the latter is supposed to have stood, to the depth of fifteen or eighteen feet, there are frequently discovered, says Mr. Hunter, entire brick walls, pillars of stone, and pieces of wood of an extraordinary hardness, besides utensils of various kinds, and ancient coins. Many coins are also found in the channels cut by the periodical rains, or in the beds of torrents into which they have been washed. "During our stay at Oujein, a large quantity of wheat was found by a man digging for bricks. It was, as might have been expected, almost entirely consumed, and in a state resembling charcoal. In a ravine cut by the rains, from which several stone pillars had been

* Vol. II. p. 172. † Vol. II. p. 147.

dug, I saw a space from twelve to fifteen feet long and seven or eight high, composed of earthen vessels, broken and closely compacted together. It was conjectured, with great appearance of probability, to have been a potter's kiln. Between this place and the new town is a hollow, in which, tradition says, the river Sipparah formerly ran. It changed its course at the time the city was buried, and now runs to the westward." *

The soil which covers Oujein is described as "being of an ash-grey colour, with minute specks of black sand." †

That the "shower of earth" which is reported to have "fallen from heaven" was produced by a volcanic eruption, seems very probable, although no information has been obtained respecting the site of the vent; and the nearest volcano of which we read is that which was in eruption during the Cutch earthquake in 1819, at the distance of about thirty miles from Bhooj, the capital of Cutch, and at least 300 geographical miles from Oujein.

Captain F. Dangerfield, who accompanied Sir John Malcolm in his late expedition into Central India, states that the river Nerbuddah, in Malwa, has its channel excavated through *columnar basalt*, above which are beds of *marl* impregnated with salt. The upper of these marls is of a light colour, and from thirty to forty feet thick, and rests horizontally on the lower bed, which is of a reddish colour. Both appear from the description to be tuffs composed of the materials of volcanic ejections, and forming a covering

* Narrative of Journey from Agra to Oujein, Asiatic Researches, vol. vi. p. 36.

† Asiatic Journal, vol. ix. p. 35.

from sixty to seventy feet deep overlying the basalt, which seems to resemble some of the currents of prismatic lava in Auvergne and the Vivarais. Near the middle of this tufaceous mass, and therefore at the depth of thirty feet or more from the surface, just where the two beds of tuff meet, Captain Dangerfield was shown, near the city of Mhysir, buried bricks and large earthen vessels, said to have belonged to the ancient city of Mhysir, destroyed by the catastrophe of Oujein.*

* Sir J. Malcolm's Cent. Ind. — Geol. of Malwa, by Captain F. Dangerfield, App. No. ii. pp. 324, 325.

CHAPTER XIV.

BURYING OF FOSSILS IN ALLUVIAL DEPOSITS AND IN CAVES.

Alluvium defined — Effects of sudden inundations — Terrestrial animals most abundantly preserved in alluvium where earthquakes prevail — Marine alluvium — Buried town — Effects of landslips — Organic remains in fissures and caves — Form and dimensions of caverns — their probable origin — Closed basins and engulphed rivers of the Morea (p. 225.) — Katavothra — Formation of breccias with red cement — Human remains imbedded in Morea — Intermixture in caves of south of France and elsewhere of human remains and bones of extinct quadrupeds no proof of former co-existence of man with those lost species (p. 235.).

Alluvium. — The next subject for our consideration, according to the division before proposed, is the imbedding of organic bodies in alluvium, by which I mean such transported matter as has been thrown down, whether by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas, — I say *permanently submerged,* in order to distinguish between *alluviums* and regular subaqueous deposits. These regular strata are accumulated in lakes or great submarine receptacles ; but the alluviums in the channels of rivers and currents, where the materials may be regarded as still *in transitu,* or on their way to a place of rest. There may be cases where it is impossible to draw a line of demarcation between these two classes of formations, but

these exceptions are rare; and the division is, upon the whole, convenient and natural.

The alluvium of the bed of a river does not often contain any animal or vegetable remains; for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand, mud, and rubbish, are suddenly swept by a flood, and then let fall upon the land, such an alluvium may envelop trees or the remains of animals, which, in this manner, are often permanently preserved. In the mud and sand produced by the floods in Scotland, in 1829, the dead and mutilated bodies of hares, rabbits, moles, mice, partridges, and even the bodies of men, were found partially buried.* But in these and similar cases one flood usually effaces the memorials left by another, and there is rarely a sufficient depth of undisturbed transported matter, in any one spot, to preserve the organic remains for ages from destruction.

Where earthquakes prevail, and the levels of a country are changed from time to time, the remains of animals may more easily be inhumed and protected from disintegration. Portions of plains, loaded with alluvial accumulations by transient floods, may be gradually upraised; and, if any organic remains have been imbedded in the transported materials, they may, after such elevation, be placed beyond the reach of the erosive power of streams. In districts where the drainage is repeatedly deranged by subterranean movements, every fissure, every hollow caused by the sink-

* Sir T. D. Lauder, Bart., on the great Floods in Morayshire Aug. 1829, p. 177.

ing in of land, becomes a depository of organic and inorganic substances, hurried along by transient floods.

Marine alluvium. — The term "marine alluvium" is, perhaps, admissible, if confined to banks of shingle thrown up like the Chesil bank in Dorsetshire, or to materials cast up by a wave of the sea upon the land, or those which a submarine current has left in its track. The kind last mentioned must necessarily, when the bed of the ocean is laid dry, resemble terrestrial alluviums; with this difference, that if any fragments of organic bodies have escaped destruction they will belong principally to marine species.

In May, 1787, a dreadful inundation of the sea was caused, at Coringa, Ingeram, and other places, on the coast of Coromandel, in the East Indies, by a hurricane blowing from the N. E., which raised the waters so that they rolled inland to the distance of about twenty miles from the shore, swept away many villages, drowned more than 10,000 people, and left the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. An old tradition of the natives of a similar flood, said to have happened about a century before, was till this event, regarded as fabulous by the European settlers.* The same coast of Coromandel was, so late as May, 1832, the scene of another catastrophe of the same kind; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa.

Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant on

* Dodsley's Ann. Regist., 1788.

them, and by the sounds heard in the ground, and the odours emitted. Such were the circumstances which accompanied the swell of the sea in Jamaica, in 1780, when a great wave desolated the western coast, and, bursting upon Savanna la Mar, swept away the whole town in an instant, so that not a vestige of man, beast, or habitation, was seen upon the surface.*

Houses and works of art in alluvial deposits. — A very ancient subterranean town, apparently of Hindoo origin, was discovered in India in 1833, in digging the Doab canal. Its site is north of Saharunpore, near the town of Behat, and 17 feet below the present surface of the country. More than 170 coins of silver and copper have already been found, and many articles in metal and earthenware. The overlying deposit consisted of about 5 feet of river sand, with a substratum about 12 feet thick, of red alluvial clay. In the neighbourhood are several rivers and torrents, which descend from the mountains charged with vast quantities of mud, sand, and shingle; and within the memory of persons now living the modern Behat has been threatened by an inundation, which after retreating left the neighbouring country strewed over with a superficial covering of sand several feet thick. In sinking wells in the environs, masses of shingle and boulders have been reached resembling those now in the river-channels of the same district, under a deposit of 30 feet of reddish loam. Captain Cautley, therefore, who directed the excavations, supposes that the matter discharged by torrents has gradually raised the whole country skirting the base of the lower hills; and that the ancient town having been originally built in a

* Edwards, Hist. of West Indies, vol. i. p. 235. ed. 1801.

hollow, was submerged by floods, and covered over with sediment 17 feet in thickness.*

We are informed, by M. Boblaye, that in the Morea, the formation termed céramique, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes an important stratum which might, in the absence of zoological characters, serve to mark our epoch in a most indestructible manner.†

Landslips.—The landslip, by suddenly precipitating large masses of rock and soil into a valley, overwhelms a multitude of animals, and sometimes buries permanently whole villages, with their inhabitants and large herds of cattle. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice ‡; and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of St. André, the ruins occupying an extent of about nine square miles. §

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than 800, a great number of the bodies, as well as several villages and scattered houses, being buried deep under mud and rock. In the same country, several hundred cottages, with eighteen of their inha-

* Journ. of Asiat. Soc., Nos. xxv. and xxix.—1834.

† Ann. des Sci. Nat., tome xxii. p. 117. Feb. 1831.

‡ Malte-Brun's Geog., vol. i. p. 435.

§ Bakewell, Travels in the Tarentaise, vol. i. p. 201.

bitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets. In the year 1618, a portion of Mount Conto fell, in the county of Chiavenna in Switzerland, and buried the town of Pleurs with all its inhabitants, to the number of 2430.

It is unnecessary to multiply examples of similar local catastrophes, which, however numerous they may have been in mountainous parts of Europe, within the historical period, have been, nevertheless, of rare occurrence when compared to events of the same kind which have taken place in regions convulsed by earthquakes. It is then that enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river-courses, and often so unexpectedly that they overwhelm, even in the daytime, every living thing upon the plains.

Preservation of Organic Remains in Fissures and Caves.

In the history of earthquakes it was shown that many hundreds of new fissures and chasms had opened in certain regions during the last 150 years, some of which are described as being of unfathomable depth. We also perceive that mountain masses have been violently fractured and dislocated, during their rise above the level of the sea; and thus we may account for the existence of many cavities in the interior of the earth by the simple agency of earthquakes; but there are some caverns, especially in limestone rocks, which, although usually, if not always, connected with rents, are nevertheless of such forms and dimensions, alternately expanding into spacious chambers, and then

contracting again into narrow passages, that it is difficult to conceive that they can owe their origin to the mere fracturing and displacement of solid masses.

In the limestone of Kentucky, in the basin of Green River, one of the tributaries of the Ohio, a line of underground cavities has been traced in one direction for a distance of ten miles, without any termination; and one of the chambers, of which there are many, all connected by narrow tunnels, is no less than ten acres in area, and 150 feet in its greatest height. Besides the principal series of "antres vast," there are a great many lateral embranchments not yet explored.*

The cavernous structure here alluded to is not altogether confined to calcareous rocks; for it has lately been observed in micaceous and argillaceous schist, in the Grecian island of Thermia (Cythnos of the ancients), one of the Cyclades. Here also spacious halls, with rounded and irregular walls, are connected together by narrow passages or tunnels, and there are many lateral branches which have no outlet. A current of water has evidently at some period flowed through the whole, and left a muddy deposit of bluish clay upon the floor; but the erosive action of the stream cannot be supposed to have given rise to the excavations in the first instance. M. Virlet suggests that fissures were first caused by earthquakes, and that these fissures became the chimneys or vents for the disengagement of gas, generated below by volcanic heat. Gases, he observes, such as the muriatic, sulphuric, fluoric, and others, might, if raised to a high

* Mem. by Nahum Ward, Trans. of Antiq. Soc. of Massachusetts. Holmes's Un. States, p. 438.

temperature, alter and decompose the rocks which they traverse. There are signs of the former action of such vapours in rents of the micaceous schist of Thermia, and thermal springs now issue from the grottos of that island. We may suppose that afterwards the elements of the decomposed rocks were gradually removed in a state of solution by mineral waters; a theory which, according to M. Virlet, is confirmed by the effect of heated gases which escape from rents in the isthmus of Corinth, and which have greatly altered and corroded the hard siliceous and jaspidious rocks.*

When we reflect on the quantity of carbonate of lime annually poured out by mineral waters, we are prepared to admit that large cavities must, in the course of ages, be formed at considerable depths below the surface in calcareous rocks.† These rocks, it will be remembered, are at once more soluble, more permeable, and more fragile, than any others, at least all the compact varieties are very easily broken by the movements of earthquakes, which would produce only flexures in argillaceous strata. Fissures once formed in limestone are not liable, as in many other formations, to become closed up by impervious clayey matter, and hence a stream of acidulous water might for ages obtain a free and unobstructed passage.‡

Morea.—After these observations on the possible origin of some subterranean hollows, I shall next consider in what manner they may be filled up with mud, pebbles, and other substances. When a mass of

* Bull. de la Soc. Géol. de France tom. ii. p. 329.

† See Vol. I. p. 307.

‡ See some remarks by M. Boblaye, Ann. des Mines, 3me série, tom. iv.

cavernous rock is raised above the level of the sea, it will usually be intersected by ravines and valleys, and it must then happen that here and there a torrent or river will break into some cavern. Accordingly, engulphed streams occur in almost every region of cavernous limestone, as in the north of England, for example; but in no district are they more conspicuous than in the Morea, where the phenomena attending them have been lately studied and described in great detail by M. Boblaye and his fellow-labourers of the French expedition to Greece.* From his account it appears that numerous caverns are there found in a compact limestone, of the age of the English chalk, immediately below which are arenaceous strata referred to the period of our green sand. In the more elevated districts of that peninsula there are many deep land-locked valleys, or basins, closed round on all sides by mountains of fissured and cavernous limestone. The year is divided almost as distinctly as between the tropics into a rainy season, which lasts upwards of four months, and a season of drought, of nearly eight months' duration. When the torrents are swollen by the rains, they rush from surrounding heights into the inclosed basins; but, instead of giving rise to lakes, as would be the case in most other countries, they are received into gulphs or chasms, called by the Greeks "Katavothra," and which correspond to what are termed "swallow-holes" in the north of England. The water of these torrents is charged with pebbles and red ochreous earth, resembling precisely the well-known cement of the osseous breccias of the Mediterranean. It dissolves

* See Ann. des Mines, 3me série, tom. iv. 1833.

in acids with effervescence, and leaves a residue of hydrated oxide of iron, granular iron, impalpable grains of silex, and small crystals of quartz. Soil of the same description abounds every where on the surface of the decomposing limestone in Greece, that rock containing in it much siliceous and ferruginous matter.

Many of the Katavothra being insufficient to give passage to all the water in the rainy season, a temporary lake is formed round the mouth of the chasm, which then becomes still farther obstructed by pebbles, sand, and red mud, thrown down from the turbid waters. The lake being thus raised, its waters generally escape through other openings, at higher levels, around the borders of the plain, constituting the bottom of the closed basin.

In some places, as at Kavaros and Tripolitza, where the principal discharge is by a gulph in the middle of the plain, nothing can be seen over the opening in summer, when the lake dries up, but a deposit of red mud, cracked in all directions. But the Katavothron is more commonly situated at the foot of the surrounding escarpment of limestone; and in that case there is sometimes room enough to allow a person to enter, in summer, and even to penetrate far into the interior. Within is seen a suite of chambers, communicating with each other by narrow passages; and M. Virlet relates, that in one instance he observed, near the entrance, human bones imbedded in recent red mud, mingled with the remains of plants and animals of species now inhabiting the Morea. It is not wonderful, he says, that the bones of man should be met with in such receptacles; for so murderous have been the

late wars in Greece, that skeletons are often seen lying exposed on the surface of the country.*

In summer, when no water is flowing into the Katavothron, its mouth, half closed up with red mud, is masked by a vigorous vegetation, which is cherished by the moisture of the place. It is then the favourite hiding-place and den of foxes and jackals; so that the same cavity serves at one season of the year for the habitation of carnivorous beasts, and at another as the channel of an engulphed river. Near the mouth of one chasm, M. Boblaye and his companions saw the carcass of a horse, in part devoured, the size of which seemed to have prevented the jackals from dragging it in: the marks of their teeth were observed on the bones, and it was evident that the floods of the ensuing winter would wash in whatsoever might remain of the skeleton.

It has been stated that the waters of all these torrents of the Morea are turbid where they are engulphed; but when they come out again, often at the distance of many leagues, they are perfectly clear and limpid, being only charged occasionally with a slight quantity of calcareous sand. The points of efflux are usually near the sea-shores of the Morea, but sometimes they are submarine; and when this is the case, the sands are seen to boil up for a considerable space, and the surface of the sea, in calm weather, swells in large convex waves. It is curious to reflect, that when this discharge fails in seasons of drought, the sea may break into subterraneous caverns, and carry in marine sand and shells, to be mingled with ossiferous mud, and the remains of terrestrial animals.

* Bull. de la Soc. Géol. de France, tom. iii. p. 223.

In general, however, the efflux of water at these inferior openings is surprisingly uniform. It seems, therefore, that the large caverns in the interior must serve as reservoirs, and that the water escapes gradually from them, in consequence of the smallness of the rents and passages by which they communicate with the surface.

The phenomena above described are not confined to the Morea, but occur in Greece generally, and in those parts of Italy, Spain, Asia Minor, and Syria, where the formations of the Morea extend. When speaking of the numerous fissures in the limestone of Greece, M. Boblaye reminds us of the famous earthquake of 469 B. C., when, as we learn from Cicero, Plutarch, Strabo, and Pliny, Sparta was laid in ruins, part of the summit of Mount Taygetus torn off, and numerous gulphs and fissures caused in the rocks of Laconia.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient water-mills were transferred.*

When the courses of engulphed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subter-

* I learnt this from some inhabitants of Sortino, in 1829, and visited the points alluded to.

ranean floods, and their carcasses buried under heaps of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be drifted along, and mixed up with mud, sand, and fragments of rocks, so as to form osseous breccias.

But it is not merely in spots where streams are engulphed that the bones of animals may be collected in rents and caverns, for open fissures often serve as natural pit-falls in which herbivorous animals perish. This may happen the more readily when they are chased by beasts of prey, or when surprised while carelessly browsing on the shrubs which so often overgrow and conceal the edges of fissures.*

During the excavations recently made near Behat in India, the bones of two deer were found at the bottom of an ancient well which had been filled up with alluvial loam. Their horns were broken to pieces, but the jaw bones and other parts of the skeleton remained tolerably perfect. "Their presence," says Capt. Cautley, "is easily accounted for, as a great number of these and other animals are constantly lost in galloping over the jungles and among the high grass by falling into deserted wells." †

Above the village of Selside, near Ingleborough in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. "The chasm," says Professor Sedgwick, "is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now

* Buckland, Reliquiæ Diluvianæ, p. 25.

† See p. 221., and places cited there.

prevented by a strong lofty wall; but there can be no doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet." *

When any of these natural pit-falls happen to communicate with lines of subterranean caverns, the bones, earth, and breccia, may sink by their own weight, or be washed into the vaults below.

We have seen that the ravines which opened in Calabria, in 1783, were very numerous, varying in their ordinary depth from fifty to two hundred feet, and that animals were sometimes engulphed during the shocks.† If a torrent chance to be in the line of any of these chasms, it might pour in a quantity of alluvial matter under which the animal remains might lie inhumed for ages. Where houses with their inhabitants have been swallowed up in fissures, there appears to have been usually a sliding in of all the loose matter which lay upon the surface; so that, in such rents, we might look for the ruins of buildings, and the skeletons of men and animals, buried in alluvium at the depth often of several hundred feet.

At the north extremity of the rock of Gibraltar are perpendicular fissures, on the ledges of which a number of hawks nestle and rear their young in the breeding season. They throw down from their nests the bones of small birds, mice, and other animals on which they

* Memoir on the Structure of the Lake Mountains of the North of England, &c., read before the Geological Society, Jan 5. 1831.

† Vol. II. p. 268.

feed, and these are gradually united into a breccia of angular fragments of the decomposing limestone with a cement of red earth.

At the pass of Escrinet in France, on the northern escarpment of the Coiron hills, near Aubenas, I have seen a breccia in the act of forming. Small pieces of disintegrating limestone are transported, during heavy rains, by a streamlet, to the foot of the declivity, where land shells are very abundant. The shells and pieces of stone soon become cemented together by stalagmite into a compact mass, and the talus thus formed is in one place fifty feet deep, and five hundred yards wide. So firmly is the lowest portion consolidated, that it is quarried for millstones.

I have lately had an opportunity of examining the most celebrated caves of Franconia, and among others that of Rabenstein, newly discovered. Their general form, and the nature and arrangement of their contents, appeared to me to agree perfectly with the notion of their having once served as the channels of subterraneous rivers. This mode of accounting for the introduction of transported matter into the Franconian and other caves, filled up as they often are even to their roofs with osseous breccia, was long ago proposed by M. C. Prevost *, and seems at length to be very generally adopted. But I do not doubt that bears inhabited some of the German caves, or that the cavern of Kirkdale, in Yorkshire, was once the den of hyænas. The abundance of bony dung, associated with hyænas' bones, has been pointed out by Dr. Buckland, and with reason, as confirmatory of this opinion.

Alternations of stalagmite and alluvium.—The same

* Mém. de la Soc. d'Hist. Nat. de Paris, tom. iv.

author observed in every cave examined by him in Germany that deposits of mud and sand, with or without rolled pebbles and angular fragments of rock, were covered over with a *single* crust of stalagmite.* In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. But Dr. Schmerling has discovered in a cavern at Chockier, about two leagues from Liège, three distinct beds of stalagmite, and between each of them a mass of breccia, and mud mixed with quartz pebbles, and in the three deposits the bones of extinct quadrupeds.†

This exception does not invalidate the generality of the phenomenon pointed out by Dr. Buckland, one cause of which may perhaps be this, that if several floods pass at different intervals of time through a subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may have been previously formed. Another cause may be, that a particular line of caverns will rarely be so situated, in relation to the lowest levels of a country, as to become, at two distinct epochs, the receptacle of engulphed rivers; and if this should happen, some of the caves, or at least the tunnels of communication, may at the first period be entirely choked up with transported matter, so as not to allow the subsequent passage of water in the same direction.

As the same chasms may remain open throughout periods of indefinite duration, the species inhabiting a country may in the mean time be greatly changed, and thus the remains of animals belonging to very different epochs may become mingled together in a common

* Reliquiæ Diluvianæ, p. 108.

† Journn. de Géol., tom. i. p. 286, July, 1830.

tomb. For this reason it is often difficult to separate the monuments of the human epoch from those relating to periods long antecedent, and it was not without great care and skill that Dr. Buckland was enabled to guard against such anachronisms in his investigation of several of the English caves. He mentions that human skeletons were found in the cave of Wokey Hole, near Wells, in the Mendips, dispersed through reddish mud and clay, and some of them united by stalagmite into a firm osseous breccia. "The spot on which they lie is within reach of the highest floods of the adjacent river, and the mud in which they are buried is evidently fluviatile.*

In speaking of the cave of Paviland on the coast of Glamorganshire, the same author states that the entire mass through which bones were dispersed appeared to have been disturbed by ancient diggings, so that the remains of extinct animals had become mixed with recent bones and shells. In the same cave was a human skeleton, and the remains of recent testacea of eatable species, which may have been carried in by man.

In several caverns on the banks of the Meuse, near Liège, Dr. Schmerling has found human bones in the same mud and breccia with those of the elephant, rhinoceros, bear, and other quadrupeds of extinct species. He has observed none of the dung of any of these animals; and from this circumstance, and the appearance of the mud and pebbles, he concludes that these caverns were never inhabited by wild beasts, but washed in by a current of water. As the human skulls and bones were in fragments, and no entire skeleton had been found, he does not believe that these caves were places of sepulture, but that the human remains

* Reliquiæ Diluvianæ, p. 165.

were washed in at the same time as the bones of extinct quadrupeds.

Caverns in the South of France. — Similar associations in the south of France, of human bones and works of art with remains of extinct quadrupeds, have induced some geologists to maintain that man was an inhabitant of that part of Europe before the rhinoceros, hyæna, tiger, and other fossil species disappeared. I may first mention the cavern of Bize, in the department of Aude, where M. Marcel de Serres met with a small number of human bones mixed with those of extinct animals and with land shells. They occur in a calcareous stony mass, bound together by a cement of stalagmite. On examining the same caverns, M. Tournal found not only in these calcareous beds, but also in a black mud which overlies a red osseous mud, several human teeth, together with broken angular fragments of a rude kind of pottery, and also recent marine and terrestrial shells. The teeth preserve their enamel; but the fangs are so much altered as to adhere strongly when applied to the tongue. Of the terrestrial shells thus associated with the bones and pottery, the most common are Cyclostoma elegans, Bulimus decollatus, Helix nemoralis, and H. nitida. Among the marine are f und Pecten jacobæus, Mytilus edulis, and Natica mille-punctata, all of them eatable kinds, and which may have been brought there for food. Bones were found in the same mass belonging to three new species of deer, an extinct bear (*Ursus arctoïdeus*), and the wild bull (*Bos urus*), formerly a native of Germany.*

* M. Marcel de Serres, Géognosie des Terrains Tertiaires, p. 64. Introduction.

In the same part of France, M. de Christol has found in caverns in a tertiary limestone at Pondres and Souvignargues, two leagues north of Lunel-viel, in the department of Herault, human bones and pottery confusedly mixed with remains of the rhinoceros, bear, hyæna, and other terrestrial mammifers. They were imbedded in alluvial mud, of the solidity of calcareous tufa, and containing some flint pebbles and fragments of the limestone of the country. Beneath this mixed accumulation, which sometimes attained a thickness of thirteen feet, is the original floor of the cavern, about a foot thick, covered with bones and the dung of animals (*album græcum*), in a sandy and tufaceous cement.

The human bones in these caverns of Pondres and Souvignargues were found, upon a careful analysis, to have parted with their animal matter to as great a degree as those of the hyæna which accompany them, and are equally brittle, and adhere as strongly to the tongue.

In order to compare the degree of alteration of these bones with those known to be of high antiquity, M. Marcel de Serres, and M. Ballard, chemist of Montpellier, procured some from a Gaulish sarcophagus in the plain of Lunel, supposed to have been buried for fourteen or fifteen centuries at least. In these the cellular tissue was empty, but they were more solid than fresh bones. They did not adhere to the tongue in the same manner as those of the caverns of Bize and Pondres, yet they had lost at least three fourths of their original animal matter.

The superior solidity of the Gaulish bones to those in a fresh skeleton is a fact in perfect accordance with the observations made by Mr. Mantell on bones taken from a Saxon tumulus near Lewes.

M. Teissier has also described a cavern near Mialet, in the department of Gard, where the remains of the bear and other animals were mingled confusedly with human bones, coarse pottery, teeth pierced for amulets, pointed fragments of bone, bracelets of bronze, and a Roman urn. Part of this deposit reached to the roof of the cavity, and adhered firmly to it. The author suggests that the exterior portion of the grotto may at one period have been a den of bears, and that afterwards the aboriginal inhabitants of the country took possession of it either for a dwelling or a burial place, and left there the coarse pottery, amulets, and pointed pieces of bone. At a third period the Romans may have used the cavern as a place of sepulture or concealment, and to them may have belonged the urn and bracelets of metal. If we then suppose the course of the neighbouring river to be impeded by some temporary cause, a flood would be occasioned, which, rushing into the open grotto, may have washed all the remains into the interior caves and tunnels, heaping the whole confusedly together.*

In the controversy which has arisen on this subject MM. Marcel de Serres, De Christol, Tournal, and others, have contended, that the phenomena of this and other caverns in the south of France prove that the fossil rhinoceros, hyæna, bear, and several other lost species, were once contemporaneous inhabitants of the country, together with man; while M. Desnoyers has supported the opposite opinion. The flint hatchets and arrow heads, he says, and the pointed bones and coarse pottery of many French and English caves, agree precisely in character with those found in the tumuli,

* Bull. de la Soc. Géol. de France, tom. ii. pp. 56—63.

and under the dolmens (rude altars of unhewn stone) of the primitive inhabitants of Gaul, Britain, and Germany. The human bones, therefore, in the caves which are associated with such fabricated objects, must belong not to antediluvian periods, but to a people in the same stage of civilization as those who constructed the tumuli and altars.

In the Gaulish monuments, we find, together with the objects of industry above mentioned, the bones of wild and domestic animals of species now inhabiting Europe, particularly of deer, sheep, wild boars, dogs, horses, and oxen. This fact has been ascertained in Quercy, and other provinces; and it is supposed by antiquaries, that the animals in question were placed beneath the Celtic altars in memory of sacrifices offered to the Gaulish divinity Hesus, and in the tombs to commemorate funeral repasts, and also from a superstition prevalent among savage nations, which induces them to lay up provisions for the manes of the dead in a future life. But in none of these ancient monuments have any bones been found of the elephant, rhinoceros, hyæna, tiger, and other quadrupeds, such as are found in caves, as might certainly have been expected, had these species continued to flourish at the time that this part of Gaul was inhabited by man.*

We are also reminded by M. Desnoyers of a passage in Florus, in which it is related that Cæsar ordered the caves into which the Aquitanian Gauls had retreated to be closed up.† It is also on record, that, so late as the eighth century, the Aquitanians defended themselves in caverns against King Pepin. As many

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 252.
† Hist. Rom. Epit., lib. iii. c. 10.

of these caverns, therefore, may have served in succession as temples and habitations, as places of sepulture, concealment, or defence, it is easy to conceive that human bones, and those of animals, in osseous breccias of much older date, may have been swept away together, by inundations, and then buried in one promiscuous heap.

It is not on the evidence of such intermixtures that we ought readily to admit either the high antiquity of the human race, or the recent date of certain lost species of quadrupeds.

CHAPTER XV.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

Division of the subject — Imbedding of terrestrial animals and plants — Increased specific gravity of wood sunk to great depths in the sea — Drift timber of the Mackenzie in Slave Lake and polar sea — Floating trees in the Mississippi (p. 245.) — in the Gulf Stream — on the coast of Iceland, Spitzbergen, and Labrador — Imbedding of the remains of insects — of reptiles — Bones of birds why rare — Imbedding of terrestrial quadrupeds by river-floods (p. 251.) — Skeletons in recent shell marl — Imbedding of mammiferous remains in marine strata.

Division of the subject.—HAVING treated of the imbedding of organic remains in deposits formed upon the land, I shall next consider the including of the same in deposits formed under water.

It will be convenient to divide this branch of our subject into three parts; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations; secondly, the modes whereby animals and plants inhabiting *fresh water* may be so entombed; thirdly, how *marine* species may become preserved in new strata.

The phenomena above enumerated demand a fuller share of attention than those previously examined, since the deposits which originate upon dry land are insignificant in thickness, superficial extent, and

durability, when contrasted with those of subaqueous origin. At the same time, the study of the latter is beset with greater difficulties; for we are here concerned with the results of processes much farther removed from the sphere of ordinary observation. There is, indeed, no circumstance which so seriously impedes the acquisition of just views in our science as an habitual disregard of the important fact, that the reproductive effects of the principal agents of change are confined to another element—to that larger portion of the globe, from which, by our very organization, we are almost entirely excluded.*

Imbedding of Terrestrial Plants.

When a tree falls into a river from the undermining of the banks, or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies in different woods; but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

Wood sunk to a great depth in the sea.—If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions †, that on one occasion a whale, on being harpooned, ran out all the lines in the boat, which it then dragged under water, to the depth of several thousand feet, the men having

* See Book i. chap. v. † Vol. ii. p. 191.

just time to escape to a piece of ice. When the fish returned to the surface "to blow," it was struck a second time, and soon afterwards killed. The moment it expired it began to sink,—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking, until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then hauled up with great labour; for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. "When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore as if they had lain at the bottom of the sea since the flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and, though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless: even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible."*

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c., to the depth of four thousand and sometimes six thousand feet, they became impregnated with sea-water, and when drawn up again, after immersion, for an hour, would no longer float. The

* Account of the Arctic Regions, vol. ii. p. 193.

effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every solid inch having increased one-twentieth in size and twenty-one twenty-fifths in weight.*

Drift-wood of the Mackenzie River.—When timber is drifted down by a river, it is often arrested by lakes; and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming: sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which vies in dimensions with some of the great fresh-water seas of Canada, the quantity of drift-timber brought down annually is enormous. "As the trees," says Dr. Richardson, "retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked; and, accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost; and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish brown substance resembling peat, but which still retains more or less of the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the

* Account of the Arctic Regions, vol. ii. p. 202.

depth of four or five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the older alluvial banks presented, or the *regular curve* that the strata assumed from unequal subsidence.

"It was in the rivers only that we could observe sections of these deposits; but the same operation goes on on a much more magnificent scale in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable debris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave River. Vast quantities of drift-timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake."*

The banks of the Mackenzie display almost every where horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding the vast forests intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood grows at present except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we

* Dr. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie is owing, as Dr. Richardson informs me, to the direction and to the length of the course of this river, which runs from south to north, so that the sources of the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the sources are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and, finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-wood of the Mississippi. — I have already observed that the navigation of the Mississippi is much impeded by trunks of trees half sunk in the river.* On reaching the Gulf of Mexico many of them subside, and are imbedded in the new strata which form the delta, but many of them float on and enter the Gulf stream. "Tropical plants (says M. Constant Prevost) are taken up by this great current, and carried in a northerly direction, till they reach the shores of Iceland and Spitzbergen uninjured. A great portion of them are doubtless arrested on their passage, and probably always in the same inlets, or the same spots on the bottom of the ocean; in fact, wherever an eddy or calm determines their distribution, which, in this single example, extends over a space comprehended between the equator and the eightieth degree

* Vol. I. p. 283.

of latitude — an immense space, six times more considerable than that occupied by all Europe, and thirty times larger than France. The drifting of various substances, though regular, is not continual; it takes place by intermittance after great inundations of rivers, and in the intervals the waters may carry sand only or mud, or each of these alternately, to the same localities."*

Drift-timber on coasts of Iceland, Spitzbergen, &c. — The ancient forests of Iceland, observes Malte-Brun, have been improvidently exhausted; but, although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees, are thrown upon the northern coast of the island, especially upon North Cape and Cape Langaness, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Crantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent.†

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch trees, pines, Siberian cedars, firs, and Fernambucco and Campeachy woods. These trunks appear to have been swept away by the great rivers of Asia and America. Some of them are

* Mém. de la Soc. d'Hist. Nat de Paris, vol. iv. p. 84.

† Malte-Brun, Geog., vol. v. part i. p. 112.—Crantz, Hist. of Greenland, tome i. pp. 50—54.

brought from the Gulf of Mexico, by the Bahama stream; while others are hurried forward by the current which, to the north of Siberia, constantly sets in from east to west. Some of these trees have been deprived of their bark by friction, but are in such a state of preservation as to form excellent building timber.* Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea, into latitudes too cold for the growth of such timber, but the trunks are usually barked.

Lighter parts of plants carried out to sea by hurricanes.— The leaves and lighter parts of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the atmosphere which sometimes accompany earthquakes and volcanic eruptions.†

Comparative number of living and fossilized species of plants.—It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers; yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of unfathomable abysses, and there accumulate without intermixture of other substances.

It may be asked whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently pre-

* Olafsen, Voyage to Iceland, tome i. Malte-Brun's Geog. vol. v. part i. p. 112.

† De la Beche, Geol. Manual, p. 477.

served, so as to be hereafter recognizable, supposing the strata now in progress to be at some future period upraised? To this inquiry it may be answered, that there are no reasons for expecting that more than a small number of the plants now flourishing in the globe will become fossilized; since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains. Suppose, for example, that the species of plants inhabiting the hydrographical basin of the Rhine, or that region, extending from the Alps to the sea, which is watered by the Rhine and its numerous tributaries, to be about 2500 in number, exclusive of the cryptogamic class. This estimate is by no means exaggerated; yet if a geologist could explore the deposits which have resulted from the sediment of the Rhine in the lake of Constance, and off the coast of Holland, he might scarcely be able to obtain from the recent strata the leaves, wood, and seeds of *fifty* species in such a state of preservation as to enable a botanist to determine their specific characters with certainty.

Those naturalists, therefore, who infer that the ancient flora of the globe was, at certain periods, less varied than now, merely because they have as yet discovered only a few hundred fossil species of a particular epoch, while they can enumerate more than fifty thousand living ones, are reasoning on a false basis, and their standard of comparison is not the same in the two cases.

Imbedding of the Remains of Insects.

I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy in Forfarshire. Amongst these, Mr. Curtis recognized Elater lineatus and Atopa cervina, species still living in Scotland. These, as well as other remains which accompanied them, appear to belong to terrestrial, not aquatic, species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon; but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are rare. In the blue clay of very modern origin of Lewes levels, Mr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera Phanorbis, Limnea, &c., adhering to them.*

When speaking of the migrations of insects, I pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or decomposed.

Remains of Reptiles.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java in the year 1699, we may imagine that extraordinary floods of

* Trans. Geol. Soc., vol. iii. part i. p. 201. second series.

mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck carried into the sea by the late inundations in Morayshire*; and it is evident that whenever a sea-cliff is undermined, or land is swept by other violent causes into the sea, land reptiles may be carried in.

Remains of Birds.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. In consequence of the hollow tubular structure of their bones and the quantity of their feathers, they are extremely light in proportion to their volume; so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals. To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

Sir T. D. Lauder records that some aquatic birds were dashed to pieces by the impetuous waters of the

* Sir T. D. Lauder's Account, second edition, p. 312.

Deveron, in Aberdeenshire, as they rushed through a narrow pass among the rocks during the floods of 1829.* In this manner torrents charged with mud may occasionally deposit the remains of birds in lacustrine strata.

Imbedding of Terrestrial Quadrupeds.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains, where herds of herbivorous quadrupeds congregate together. These animals are often surprised; and being unable to stem the current, are hurried along until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth, or at latest the fourteenth day. The pressure of a thin covering of mud would not be sufficient to retain them at the bottom; for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and in sea-water they would be still more buoyant.

Where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random

* Account of the Great Floods, &c., second ed. p. 330.

over the bottom of a lake, estuary, or sea; so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third—all included, perhaps, in a matrix of fine materials, where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are instantly devoured by sharks, alligators, and other carnivorous beasts, which may have power to digest even the bones; but during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water, lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of carcasses becoming permanently imbedded is considerable.

Flood in the Solway Firth, 1794.—One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of Scotland, on the 24th of January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway; so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank, called "the beds of

Esk," where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of 9 black cattle, 3 horses, 1840 sheep, 45 dogs, 180 hares, besides a great number of smaller animals, and, mingled with the rest, the corpses of two men and one woman.*

Floods in Scotland, 1829.— In those more recent floods in Scotland, in August, 1829, whereby a fertile district, on the east coast, became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire: —"For several miles along the beach crowds were employed in endeavouring to save the wood and other wreck with which the heavy-rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits. Thousands of living frogs, also, swept from the fields, no one can say how far off, were observed leaping among the wreck." †

Savannahs of South America.—We are informed by Humboldt, that during the periodical swellings of the large rivers in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, thousands are said to perish when the river Apure is swollen, before they have time to reach the rising ground of the Llanos. The mares, during the

* Treatise on Practical Store Farming, p. 25.

† Sir T. D. Lauder's Floods in Morayshire, 1829, p. 312., second ed.; and see above, Vol. I. p. 262.

season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. "Such is the pliability," observes the celebrated traveller, "of the organization of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring."*

Floods of the Ganges.— We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen.†

In Java, 1699.—I have already referred to the effects of a flood which attended an earthquake in Java in 1699, when the turbid waters of the Batavian river destroyed all the fish except the carp; and when drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud.‡

On the western side of the same island, in the territory of Goulongong, in the Regencies, a more recent

* Humboldt's Pers. Nar., vol. iv. pp. 394—396.

† Malte-Brun, Geog., vol. iii. p. 22.

‡ See Vol. II. p. 304.

volcanic eruption (1821) was attended by a flood, during which the river Tjetandoy bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than one hundred men and women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed.*

In Virginia, 1771.—I might enumerate a great number of local deluges that have swept through the fertile lands bordering on large rivers, especially in tropical countries, but I should surpass the limits assigned to this work. I may observe, however, that the destruction of the islands, in rivers, is often attended with great loss of lives. Thus when the principal river in Virginia rose, in 1771, to the height of twenty-five feet above its ordinary level, it swept entirely away Elk Island, on which were seven hundred head of quadrupeds,—horses, oxen, sheep, and hogs,—and nearly one hundred houses.†

The reader will gather, from what was before said respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in freshwater formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither

* This account I had from Mr. Baumhauer, Director-General of Finances in Java.

† Scots Mag., vol. xxxiii.

no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Skeletons of animals in recent shell-marl, Scotland.— In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in, Scotland. The remains of several hundred skeletons have been procured within the last century, from five or six small lakes in Forfarshire, where shell-marl has been worked. Those of the stag (*Cervus elaphus*) are most numerous; and if the others be arranged in the order of their relative abundance, they will follow nearly thus:— the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare; but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

In the greater part of these lake deposits there are no signs of floods; and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed, by swimming, from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape may have plunged deeper into the marly bottom. Some individuals, I suspect, of different species, have fallen in when crossing the frozen surface in winter; for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs,

which are numerous, and which, retaining always an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other part of the lake it is strong enough to bear the heaviest weights.

Mammiferous remains in marine strata.—As the bones of mammalia are often so abundantly preserved in peat, and such lakes as have just been described, the encroachments of a sea upon a coast may sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in subaqueous formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although I believe it to be of comparatively small importance amongst the numerous agents whereby terrestrial organic remains are included in submarine strata.

CHAPTER XVI.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

Drifting of human bodies to the sea by river inundations — Destruction of bridges and houses — Loss of lives by shipwreck — How human corpses may be preserved in recent deposits — Number of wrecked vessels — Fossil skeletons of men (p. 265.) — fossil canoes, ships, and works of art — Chemical changes which metallic articles have undergone after long submergence — Imbedding of cities and forests in subaqueous strata by subsidence (p. 272.) — Earthquake of Cutch in 1819 — Submarine forests — Example on coast of Hampshire — Origin of a submarine forest — Berkley's arguments for the recent date of the creation of man (p. 278.) — Concluding remarks.

I SHALL now proceed to inquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in the course of a few thousand years; but of the smaller number that perish in the waters, a considerable proportion must frequently be entombed under such circumstances, that parts of them may endure throughout entire geological epochs.

The bodies of men, together with those of the inferior animals, are occasionally washed down during river inundations into seas and lakes.* Belzoni wit-

* See pp. 253. 255.

nessed a flood on the Nile in September, 1818, where, although the river rose only three feet and a half above its ordinary level, several villages, with some hundreds of men, women, and children, were swept away.* It was before mentioned that a rise of six feet of water in the Ganges, in 1763, was attended with a much greater loss of lives.†

In the year 1771, when the inundations in the north of England appear to have equalled the recent floods in Morayshire, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep, were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically. As the population increases, and buildings and bridges are multiplied, we must expect the loss of lives and property to augment.‡

Fossilization of human bodies in the bed of the sea.—If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwreck, we shall find that, in the course of a single year, a great number of human

* Narrative of Discovery in Egypt, &c., London, 1820.

† Vol. I. p. 359.

‡ Scots Mag., vol. xxxiii., 1771.

remains are consigned to the subaqueous regions. I shall hereafter advert to a calculation by which it appears that more than five hundred *British* vessels alone, averaging each a burthen of about one hundred and twenty tons, are wrecked, and sink to the bottom, *annually*. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them; but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of a river is advancing, they may be preserved for an incalculable series of ages.

Often at the distance of a few hundred feet from a coral reef, where wrecks are not unfrequent, there are no soundings at the depth of many hundred fathoms. Canoes, merchant vessels, and ships of war, may have sunk and have been enveloped, in such situations, in calcareous sand and breccia, detached by the breakers from the summit of a submarine mountain. Should a volcanic eruption happen to cover such remains with ashes and sand, and a current of lava be afterwards poured over them, the ships and human skeletons might remain uninjured beneath the superincumbent mass, like the houses and works of art in the subterranean cities of Campania. Already many human remains have been thus preserved beneath formations more than a thousand feet in thickness; for, in some volcanic archi-

pelagos, a period of thirty or forty centuries might well be supposed sufficient for such an accumulation.

It was stated that, at the distance of about forty miles from the base of the delta of the Ganges, there is a circular space about fifteen miles in diameter where soundings of a thousand feet sometimes fail to reach the bottom.* As during the flood season the quantity of mud and sand poured by the great rivers into the Bay of Bengal is so great that the sea only recovers its transparency at the distance of sixty miles from the coast, this depression must be gradually shoaling, especially as during the monsoons the sea, loaded with mud and sand, is beaten back in that direction towards the delta. Now, if a ship or human body sink down to the bottom in such a spot, it is by no means improbable that it may become buried under a depth of three or four thousand feet of sediment in the same number of years.

Even on that part of the floor of the ocean to which no accession of drift matter is carried (a part which probably constitutes, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom, and is overturned; in which case the ballast, consisting of sand, shingle, and rock, or the cargo, frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case

* Vol. I. p. 355.

of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel as they decay, and beneath these and the metallic substances the bones of man may be preserved.

Number of wrecked vessels. — When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven 50-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace; many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water.

But let it not be imagined that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in

the bed of the sea. From an examination of Lloyd's lists, from the year 1793 to the commencement of 1829, Capt. W. H. Smyth ascertained that the number of *British vessels* alone lost during that period amounted on an average to no less than one and a half *daily;* an extent of loss which would hardly have been anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at one time, in the navigation of England and Scotland, amounts to about twenty thousand, having one with another a mean burthen of 120 tons.* My friend, Mr. J. L. Prevost, also informs me that on inspecting Lloyd's lists for the years 1829, 1830, and 1831, he finds that no less than 1953 vessels were lost in those three years, their average tonnage being above 150 tons, or in all nearly 300,000 tons, being at the enormous rate of 100,000 tons annually of the merchant vessels of one nation only. This increased loss arises, I presume, from increasing activity in commerce.

Out of 551 ships of the royal navy lost to the country during the period above mentioned, only 160 were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident; a striking proof that the dangers of our naval warfare, however great, may be far exceeded by the storm, the shoal, the lee-shore, and all the other perils of the deep.†

Durable nature of many of their contents. — Millions of silver dollars and other coins have been sometimes submerged in a single ship, and on these, when they

* Cæsar Moreau's Tables of the Navigation of Great Britain.

† I give these results on the authority of Captain W. H. Smyth, R.N.

happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants in some of the ancient secondary rocks. In almost every large ship, moreover, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved — engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was, therefore, a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

> ——— as rich with praise
> As is the ooze and bottom of the deep
> With sunken wreck and sumless treasuries;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will be seen at any one time on the surface of the continents.

If our species be of as recent a date as is generally supposed, it will be vain to seek for the remains of man and the works of his hands imbedded in submarine strata, except in those regions where violent earthquakes are frequent, and the alterations of relative level so great, that the bed of the sea may have been converted into land within the historical era. We need not despair, however, of the discovery of such monuments when those regions which have been peopled by man from the earliest ages, and which are at

the same time the principal theatres of volcanic action, shall be examined by the joint skill of the antiquary and geologist.

Power of human remains to resist decay. — There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior animals; and I have already cited the remark of Cuvier, that "in ancient fields of battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave."* In the delta of the Ganges bones of men have been found in digging a well at the depth of ninety feet†; but as that river frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Fossil skeletons of men. — Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement resembling travertin, by which also the different grains are bound together. The lens show that some of the fragments of coral composing this stone still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the Bulimus Guadaloupensis of

* Vol. I. p. 241. † Von Hoff, vol. i. p. 379.

Férussac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to Mr. König, the rock in which the former is inclosed is harder under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Similar formations are in progress in the whole of the West-Indian archipelago, and they have greatly extended the plain of Cayes in St. Domingo, where fragments of vases and other human works have been found at a depth of twenty feet. In digging wells also near Catania, in Sicily, tools have been discovered in a rock somewhat similar.

Buried ships, canoes, and works of art.—When a vessel is stranded in shallow water, it usually becomes the nucleus of a sand-bank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. About fifty years ago, a vessel from Purbeck, laden with three hundred tons of stone, struck on a shoal off the entrance of Poole harbour and foundered; the crew were saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that Point.* The cause is obvious; the tidal current deposits the

* This account I received from the Honourable Chas. Harris.

sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it, just as the African sand-winds, before described, raise a small hillock over the carcass of every dead camel exposed on the surface of the desert.

I before alluded to an ancient Dutch vessel, discovered in the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged.* The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vessel and two anchors in a very perfect state were dug up far from the sea.†

At the mouth of a river in Nova Scotia, a schooner of thirty-two tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about ten feet in perpendicular height, rushed into the estuary and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand, that the taffrel or upper rail over the stern was alone visible.‡ We are informed by Leigh, that on draining Martin Meer, a lake eighteen miles in

* Vol. II. p.42. † Von Hoff, vol. i. p. 368.

‡ Silliman's Geol. Lectures, p.78., who cites Penn.

circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this Meer a whetstone and an axe of mixed metal were dug up.* In Ayrshire also, three canoes were found in Loch Doon some few years ago; and during the year 1831 four others, each hewn out of separate oak trees. They were twenty-three feet in length, two and a half in depth, and nearly four feet in breadth at the stern. In the mud which filled one of them was found a war-club of oak and a stone battle-axe. A canoe of oak was also found in 1820, in peat overlying the shell-marl of the Loch of Kinnordy in Forfarshire.†

Manner in which ships may be preserved in a deep sea. — It is extremely possible that the submerged woodwork of ships which have sunk where the sea is two or three miles deep has undergone greater chemical changes in an equal space of time, than in the cases above mentioned; for the experiments of Scoresby show that wood may at certain depths be impregnated in a single hour with salt-water, so that its specific gravity is entirely altered. It may often happen that hot springs charged with carbonate of lime, silex, and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion also of wood into lignite is probably more rapid under enormous pres-

* Leigh's Lancashire, p. 17., A.D. 1700.

† Geol. Trans., second ser., vol. ii. p. 87.

sure. But the change of the timber into lignite or coal would not prevent the original form of a ship from being distinguished; for, as we find in strata of the carboniferous era, the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal; while in the indurated mud, sandstone, or limestone, filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Submerged metallic substances. — Many of the metallic substances which fall into the waters probably lose, in the course of ages, the forms artificially imparted to them; but under certain circumstances these may be preserved for indefinite periods. The cannon inclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long as the calcareous matrix; but even if the metallic matter had been removed, and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen, sweeping for anchors in the Gull stream (a part of the sea near the Downs), drew up a very curious old swivel gun, near eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of an exceedingly strong

texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there was no such incrustation, the greater part of it being clean, and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, "just as they are often found in a fossil state." These were all so strongly attached, that it required as much force to separate them from the matrix "as to break a fragment off any hard rock."*

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian, and went to pieces. About thirty-three years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses, "consisting of iron, ropes, and balls," covered over with ochreous sand, concreted and hardened into a kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, "just as impressions of extraneous fossil bodies are found in various kinds of strata."†

After a storm, in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's, in Scotland, a gun-barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of the Spanish Armada. It is now in the museum of the Antiquarian Society of Scotland, and is incrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common cardium, mya, &c.

* Phil. Trans., 1779.

† Ibid., vol. lxix., 1779.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coasts, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes, a bronze helmet, of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially incrusted with shells, and a deposit of carbonate of lime. The surface generally, both under the incrustation, and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

The mineralizing process, says Dr. Davy, which has produced these new combinations, has, in general, penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath; in some places considerably corroded, in others very slightly. It proves, on analysis, to be copper, alloyed with 18·5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility.

"It is a curious question," he adds, "how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralizing process depends on a small motion and separation of the particles of the original compound? This motion may have been

due to the operation of electro-chemical powers which may have separated the different metals of the alloy."*

Effects of the Subsidence of Land, in imbedding Cities and Forests in subaqueous Strata.

We have hitherto considered the transportation of plants and animals from the land by *aqueous* agents, and their inhumation in lacustrine or submarine deposits, and we may now inquire what tendency the subsidence of tracts of land by *earthquakes* may have to produce analogous effects. Several examples of the sinking down of buildings, and portions of towns near the shore, to various depths beneath the level of the sea during subterranean movements, were before enumerated in treating of the changes brought about by *inorganic* causes. The events alluded to were comprised within a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable changes in the physical geography of the globe. If, during the earthquake of Jamaica, in 1692, some of the houses in Port Royal subsided, together with the ground they stood upon, to the depth of twenty-four, thirty-six, and forty-eight feet under water, we are not to suppose that this was the only spot throughout the whole range of the coasts of that island, or the bed of the surrounding sea, which suffered similar depressions. If the quay at Lisbon sunk at once to the depth of several hundred feet in 1755, we must not imagine that this was the only

* Phil. Trans. 1826, part ii. p. 55.

point on the shores of the peninsula where similar phenomena might have been witnessed.

If, during the short period since South America has been colonized by Europeans, we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception *, we cannot for a moment suspect that these cities, so distant from each other, have been selected as the peculiar points where the desolating power of the earthquake has expended its chief fury. "It would be a knowing arrow that could choose out the brave men from the cowards," retorted the young Spartan, when asked if his comrades who had fallen on the field of battle were braver than he and his fellow-prisoners; we might, in the same manner, remark that a geologist must attribute no small discrimination and malignity to the subterranean force, if he should suppose it to spare habitually a line of coast many thousand miles in length, with the exception of those few spots where populous towns have been erected. On considering how small is the area occupied by the seaports of this disturbed region,—points where alone each slight change of the relative level of the sea and land can be recognized, and reflecting on the proofs in our possession, of the local revolutions that have happened on the site of each port, within the last century and a half—our conceptions must be greatly exalted respecting the magnitude of the alterations which the country between the Andes and the sea may have undergone, even in the course of the last six thousand years.

Cutch earthquake.—The manner in which a large

* See Vol. II. pp. 231. 300. 302.

extent of surface may be submerged, so that the terrestrial plants and animals may be imbedded in subaqueous strata, cannot be better illustrated than by the earthquake of Cutch, in 1819, before alluded to.* It is stated, that, for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon formed by subsidence, on the site of the village of Sindree and its environs; but, after the flood of 1826, they were seen no longer. Every geologist will at once perceive, that forests sunk by such subterranean movements may become imbedded in subaqueous deposits, both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Submarine forests.—But, although a certain class of geological phenomena may be referred to the repetition of such catastrophes, we must hesitate before we call in to our aid the action of earthquakes, to explain what have been termed submarine forests, observed at various points around the shores of Great Britain. I have already hinted, that the explanation of some of these may be sought in the encroachments of the sea, in estuaries, and the varying level of the tides, at distant periods, on the same parts of our coast.† After examining, in 1829, the submarine forest as it is called of Happisborough, in Norfolk, I found that it was nothing more than a tertiary lignite; which becomes exposed in the bed of the sea as soon as

* Vol. II. p. 237. † Vol. II. p. 27.

the waves sweep away the superincumbent strata of blueish clay. So great has been the advance of the sea upon our eastern shores, within the last eight centuries, that whenever we find a mass of submerged timber near the sea-side, or at the foot of the existing cliffs, which we cannot suppose to be a mere accumulation of drift vegetable matter, we should endeavour to find a solution of the problem, by reference to any cause rather than an earthquake. For we can scarcely doubt that the present outline of our coast, the shape of its estuaries, and the formation of its cliffs, are of very modern date, probably within the historical era; whereas we have no reason whatever to imagine that this part of Europe has been agitated by subterranean convulsions, capable of altering the relative level of land and sea, at so recent a period.

In Scotland.—It has been observed, by Dr. Fleming, that the roots of the trees, in several submarine forests in Scotland, are in lacustrine silt. The stumps of the trees evidently occupy the position in which they formerly grew, and are sometimes from eight to ten feet below high-water mark. The horizontality of the strata, and other circumstances, preclude the supposition of a slide; and the countries in question have been, from time immemorial, free from violent earthquakes, which might have produced subsidences. He has, therefore, attributed the depression, with much probability, to the drainage of peaty soil, on the removal of a seaward barrier. Suppose a lake, separated from the sea by a chain of sand hills, to become a marsh, and a stratum of vegetable matter to be formed on the surface, of sufficient density to support trees. Let the outlet of the marsh be elevated a few feet only above the rise of the tide. All the strata

below the level of the outlet would be kept constantly wet, or in a semifluid state; but if the tides rise in the estuary, and the sea encroaches, portions of the gained lands are swept away, and the extremities of the alluvial and peaty strata, whereon the forest grew, are exposed to the sea, and at every ebb tide left dry to a depth equal to the increased fall of the tide. Much water, formerly prevented from escaping, now oozes out from the moist beds,—the strata collapse, and the surface of the morass, instead of remaining at its original height, sinks below the level of the sea.*

Submarine forest on coast of Hants, how formed. — Mr. Charles Harris discovered lately evident traces of a fir-wood, beneath the mean level of the sea, at Bournmouth, in Hampshire, the formation having been laid open during a low spring tide. It is composed of peat and wood, and is situated between the beach and a bar of sand about 200 yards off, and extends fifty yards along the shore. It also lies in the direct line of the Bournmouth Valley, from the termination of which it is separated by 200 yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch trees, and a great abundance of the Myrica gale. Seventy-six rings of annual growth were counted in a transverse section of one of the buried fir trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, pieces of alder and birch are found in the peat; and it is a curious fact, that a part of many of the trees has been converted into iron pyrites. The

* See Memoirs by the Rev. Dr. Fleming, Trans. R. S. Edin., vol. ix. p. 419.; and Quarterly Journ. of Sci., No. 13., new series.

peat rests on pebbly strata, precisely similar to the sand and pebbles occurring on the adjoining heaths.

As the sea is encroaching on this shore, we may suppose that at some former period the Bourne Valley extended farther, and that its extremity consisted, as at present, of boggy ground, partly clothed with fir-trees. The bog rested on that bed of pebbles which we now see below the peat; and the sea, in its progressive encroachments, eventually laid bare, at low water, the sandy foundations; upon which a stream of fresh water rushing through the sand at the fall of the tides, carried out loose sand with it. The superstratum of vegetable matter being matted and bound together by the roots of trees, remained; but being undermined, sank down below the level of the sea, and then the waves washed sand and shingle over it. In support of this hypothesis, it may be observed, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dry-shod; and the water is seen, at the point where it issues, to carry out sand, and even pebbles.

Buildings how preserved under water. — Some of the buildings which have at different times subsided beneath the level of the sea have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and at the site of the Temple of Serapis, in the environs of Puzzuoli, probably in the twelfth century. The entrance of a river charged with sediment in the vicinity may still more frequently occasion the rapid envelopment of buildings in regularly stratified formations. But if no foreign matter be introduced, the buildings, when once removed to a depth where the

action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and I am informed by an eye-witness that eighty-eight years after the convulsion of 1692, the houses of Port Royal were still visible at the bottom of the sea.*

Berkley's arguments for the recent date of the creation of man. — I cannot conlude this chapter without recalling to the reader's mind a memorable passage written by Berkley a century ago, in which he inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. "To any one," says he, "who considers that on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there in all probability some thousands of years; it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of

* Admiral Sir Charles Hamilton frequently saw the submerged houses of Port Royal in the year 1780, in that part of the harbour which lies between the town and the usual anchorage of men-of-war. Bryan Edwards also says, in his History of the West Indies (vol. i. p. 235., oct. ed., 3 vols. 1801,) that in 1793 the *ruins* were visible in clear weather from the boats which sailed over them.

buildings, no public monuments, no intaglias, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times."*

That many signs of the agency of man would have lasted at least as long as "the shells of the primeval world," had our race been so ancient, we may feel as fully persuaded as Berkley; and we may anticipate with confidence that many edifices and implements of human workmanship, and the skeletons of men, and casts of the human form, will continue to exist when a great part of the present mountains, continents, and seas, have disappeared. Assuming the future duration of the planet to be indefinitely protracted, we can foresee no limit to the perpetuation of some of the

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

memorials of man, which are continually entombed in the bowels of the earth or in the bed of the ocean, unless we carry forward our views to a period sufficient to allow the various causes of change, both igneous and aqueous, to remodel more than once the entire crust of the earth. *One* complete revolution will be inadequate to efface every monument of our existence; for many works of art might enter again and again into the formation of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organized remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, "that none of the works of a mortal being can be eternal." * They are in the first place wrested from the hands of man, and lost as far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish; for every year some portion of the earth's crust is shattered by earthquakes or melted by volcanic fire, or ground to dust by the moving waters on the surface. "The river of Lethe," as Bacon eloquently remarks, "runneth as well above ground as below." †

* Davy, Consolations in Travel, p. 276.

† Essay on the Vicissitude of Things.

CHAPTER XVII.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

Inhumation of fresh-water plants and animals — Shell marl — Fossilized seed-vessels and stems of chara — Recent deposits in American lakes — Fresh-water species drifted into seas and estuaries — Lewes levels — Alternations of marine and fresh-water strata, how caused — Imbedding of marine plants and animals (p. 288.) — Cetacea stranded on our shores — Liability of littoral and estuary testacea to be swept into the deep sea — Effects of a storm in the Firth of Forth — Burrowing shells secured from the ordinary action of waves and currents — Living testacea found at considerable depths — Extent of some recent shelly deposits.

Having treated of the imbedding of terrestrial plants and animals, and of human remains, in deposits now forming beneath the waters, I come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

Fresh-water plants and animals. — The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh water are for the most part preserved in the beds of lakes or estuaries, but they are oftentimes swept down by rivers into the sea, and there intermingled with the exuviæ of marine races. The phenomena attending their inhumation in lacustrine deposits are sometimes revealed to our observation by

the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell marl for agricultural uses.

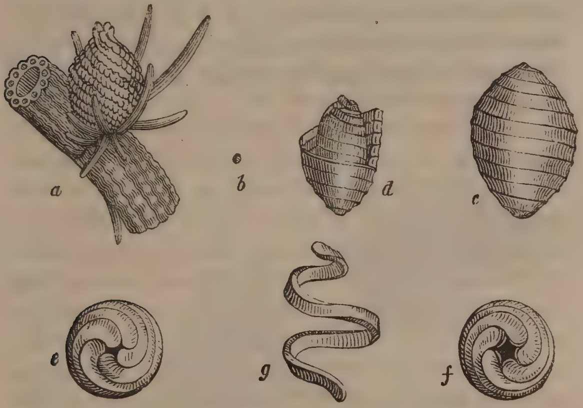
In these recent formations, as seen in Forfarshire, two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera limnea, planorbis, valvata, and cyclas, of species now existing in Scotland. A considerable proportion of the testacea appear to have died very young, and few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes in a state of good preservation. They are frequently intermixed with stems of charæ and other aquatic vegetables, the whole being matted together and compressed, forming laminæ often as thin as paper.

Fossilized seed-vessels and stems of chara.—As the chara is an aquatic plant, which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterizing entire groups of strata, I shall describe the manner in which I have found the recent species in a petrified state. They occur in a marl-lake in Forfarshire, inclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

The seed-vessel of these plants is remarkably tough and hard, and consists of a membranous nut covered by an integument (*d*, fig. 52.), both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of a quadrangular form (*g*). In *Chara hispida*, which abounds in the lakes of Forfar-

shire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

Fig. 52.



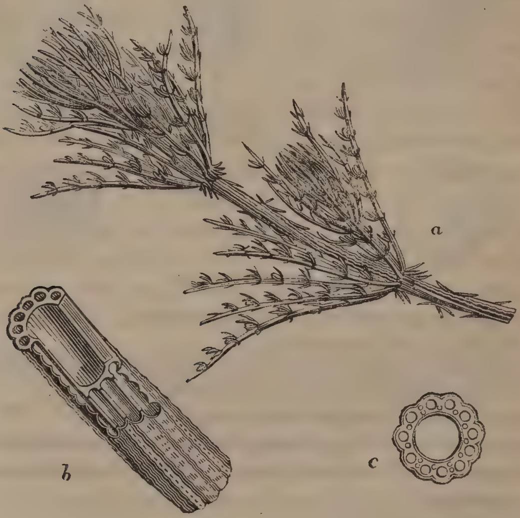
Seed-vessel of Chara hispida.

a. Part of the stem with the seed-vessel attached. Magnified.
b. Natural size of the seed-vessel.
c. Integument of the Gyrogonite, or petrified seed-vessel of Chara hispida, found in the Scotch marl-lakes. Magnified.
d. Section showing the nut within the integument.
e. Lower end of the integument to which the stem was attached.
f. Upper end of the integument to which the stigmata were attached.
g. One of the spiral valves of *c*.

The stems of charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida,* the plant when living contains so much carbonate of lime in its vegetable organization, independ-

ently of calcareous incrustation, that it effervesces strongly with acids when dry. The stems of *Chara hispida* are longitudinally striated, with a tendency to be spiral. These striæ, as appears to be the case with all charæ, turn always like the worm of a screw from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (fig. 53. *b*, *c*), as is seen in some extinct as well as recent species.

Fig. 53.



Stem and branches of Chara hispida.

a. Stem and branches of the natural size.

b. Section of the stem magnified.

c. Showing the central tube surrounded by two rings of smaller tubes.

In the stems of several species, however, there is only a single tube.*

The valves of a small animal called cypris (*C. ornata?* Lam.) occur completely fossilized like the stems of charæ, in the Scotch travertin above mentioned. This cypris inhabits the lakes and ponds of England, where it is not uncommon. Species of the same genus also occur abundantly in ancient fresh-water formations.†

Recent deposits in North American lakes.—The recent strata of lacustrine origin above alluded to are of very small extent, but analogous deposits on the grandest scale are forming in the great lakes of North America. By the subsidence of the waters of Lakes Superior and Huron, occasioned probably by the partial destruction of their barriers at some unknown period, beds of sand 150 feet thick are exposed, below which are seen beds of clay, inclosing shells of the very species which now inhabit the lake.‡

But no careful examination appears as yet to have been made of recent fresh-water formations within the tropics, where the waters teem with life, and where in the bed of a newly drained lake the remains of the alligator, crocodile, tortoise, and perhaps some large fish, might be discovered.

Imbedding of fresh-water Species in Estuary aud Marine Deposits.

In Lewes levels.—We have sometimes an opportunity of examining the deposits which within the historical

* On Fresh-water Marl, &c. By C. Lyell. Geol. Trans., vol. ii., second series, p. 73.

† For figures of Cypris, see Book IV. chap. xvii.

‡ Dr. Bigsby, Journal of Science, &c. No. xxxvii. pp. 262, 263.

period have silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouze between Newhaven and Lewes is one of several estuaries from which the sea has retired within the last seven or eight centuries; and here, as appears from the researches of Mr. Mantell, strata thirty feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about five feet thick, inclosing many trunks of trees. Next below is a stratum of blue clay containing fresh-water shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned fresh-water shells, several marine species well known on our coast. In the lowest beds, often at the depth of thirty-six feet, these marine testacea occur without the slightest intermixture of fluviatile species, and amongst them the skull of the narwal, or sea unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk.*

If we had no historical information respecting the former existence of an inlet of the sea in this valley, and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine testacea identical with

* Mantell, Geol. of Sussex, p. 285.; also Catalogue of Org. Rem., Geol. Trans., vol. iii. part i. p. 201., second series.

those now living, and into which some of the larger cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of fresh-water and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued until the river-water prevailed, so that it was no longer habitable by marine testacea, but fitted only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed where some trees grew, or perhaps were drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being flooded by the river only at distant intervals, became a verdant meadow.

In delta of Ganges. — It was before stated, that on the sea-coast, in the delta of the Ganges, there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge.* Now, as the base of the delta is 200 miles in length, it must happen that, as often as the great volume of river-water is thrown into the sea by a new mouth, the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the exception of those parts where the principal discharge takes place, the salt-water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident, then, that repeated alternations of beds containing fresh-water shells, with others filled with corals and marine exuviæ, may here be formed; and each series may be of great thickness, as the sea on which the Gangetic delta gains is of considerable depth, and intervals of cen-

* Vol. I. p. 354.

turies elapse between each alteration in the course of the principal stream.

In delta of Indus. — Analogous phenomena must sometimes be occasioned by such alternate elevation and depression of the land as was shown to be taking place in the delta of the Indus.* But the subterranean movements affect but a small number of the deltas formed at one period on the globe; whereas, the silting up of some of the arms of great rivers and the opening of others, and the consequent variation of the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small, but the abundance of individuals extremely great, a circumstance very characteristic of fresh-water formations in general as compared to marine; for in the latter, as is seen on sea-beaches, coral reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

Imbedding of the Remains of Marine Plants and Animals.

Marine plants. — The large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans were before alluded to.† These, when they subside, may often produce considerable beds of vegetable matter. In Holland, submarine peat is derived from fuci, and on parts of

* Vol. II. p. 237. † Vol. III. p. 37.

our own coast from *Zostera marina.* In places where algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Cetacea.—It is not uncommon for the larger cetacea, which can float only in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high water, they are stranded. Thus a narwal (*Monodon monoceros*) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn and tried to pull it out, when the animal began to stir itself.* An individual of the common whale (*Balæna mysticetus*), which measured seventy feet, came ashore near Peterhead, in 1682. Many individuals of the genus Balænoptera have met the same fate. It will be sufficient to refer to those cast on shore near Burnt Island, and at Alloa, recorded by Sibbald and Neill. The other individual mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a Razor-back. Of the genus Catodon (*Cachalot*) Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of 100 in number, were found stranded at Kairston, in Orkney. The dead bodies of the larger cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the

* Fleming's Brit. Animals, p. 37.; in which work may be seen many other cases enumerated.

carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith.

To some accident of this kind, we may refer the position of the skeleton of a whale seventy-three feet long, which was found at Airthrey, on the Forth, near Alloa, imbedded in clay twenty feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman station and causeways at a small distance from the spot, it is concluded that the whale must have been stranded there at a period prior to the Christian era.*

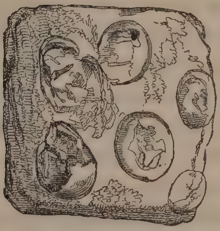
Other fossil remains of this class have also been found in estuaries, known to have been silted up in recent times, one example of which has been already mentioned near Lewes, in Sussex.

Marine reptiles. — Some singular fossils have lately been discovered in the island of Ascension in a stone said to be continually forming on the beach where the waves throw up small rounded fragments of shells and corals, which, in the course of time, become firmly agglutinated together and constitute a stone used largely for building and making lime. In a quarry on the N. W. side of the island, about 100 yards from the sea, some fossil eggs of turtles have been discovered in the hard rock thus formed. The eggs must have been nearly hatched at the time when they perished; for the bones of the young turtle are seen in the interior with their shape fully developed, the interstices between the bones being entirely filled with grains of sand, which are cemented together so that when the egg-shells are removed perfect casts of their form re-

* Quart. Journ. of Lit. Sci., &c. No. 15. p. 172. Oct. 1819.

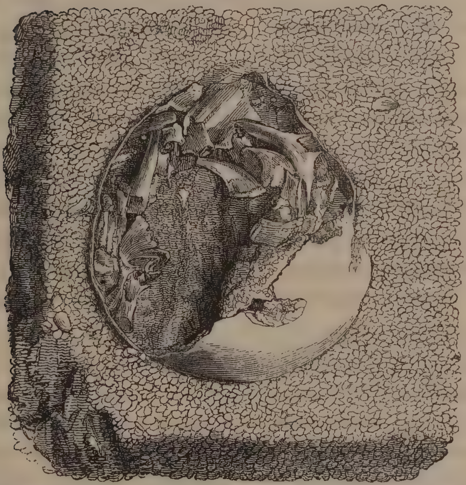
main in stone. In the single specimen here figured

Fig. 54.



*Fossil eggs of Turtles from the Island of Ascension.**

Fig. 55.



One of the eggs in Fig. 54. of the natural size, showing the bones of the fœtus which had been nearly hatched.

* This specimen is in the possession of Mr. Carrier of the Geological Society of London.

(Fig. 54.), which is only five inches in its longest diameter, no less than seven eggs are preserved.*

To explain the state in which they occur fossil, it seems necessary to suppose that after the eggs were almost hatched in the warm sand, a great wave threw upon them so much more sand as to prevent the rays of the sun from penetrating, so that the yolk was chilled and deprived of vitality. The shells were perhaps slightly broken at the same time, so that small grains of sand might gradually be introduced into the interior by water as it percolated through the beach.

Marine testacea.—The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep; for as a river is perpetually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud, against which it turns its force. These banks may consist in great measure of shells peculiar to shallow, and sometimes brackish water, which may have been accumulating for centuries, until at length

* The most conspicuous of the bones represented within the shell in Fig. 55., appear to be the clavicle and coracoid bone. They are hollow; and for this reason resemble, at first sight, the bones of birds rather than of reptiles; for the latter have no medullary cavity. Mr. Owen, of the College of Surgeons, in order to elucidate this point, dissected for me a very young turtle, and found that the exterior portion only of the bones was ossified, the interior being still filled with cartilage. This cartilage soon dried up, and shrunk to a mere thread upon the evaporation of the spirits of wine in which the specimen had been preserved, so that in a short time the bones became as empty as those of birds.

they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable even than fresh-water species, to be intermixed with the exuviæ of pelagic tribes.

After the storm of February 4. 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high-water mark. I collected many of these oysters, as also the common eatable whelks (*buccina*), thrown up with them, and observed that, although still living, their shells were worn by the long attrition of sand which had passsd over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they were cast ashore.

From these facts we learn that the union of the two parts of a bivalve shell does not prove that it has not been transported to a distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells. — It sometimes appears extraordinary, when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs, and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve testacea, and many also of the turbinated univalves, burrow in sand or mud. The solen and the cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the

pholas can drill a cavity through mud of considerable hardness. The species of these and many other tribes can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these testacea may remain below secure and uninjured.

Shells become fossil at considerable depths. — I have already stated that, at the depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smyth found a gravelly bottom, with fragments of broken shells, carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for even in our own colder latitudes, the depths at which living marine animals abound is very considerable. Captain Vidal ascertained, by soundings lately made off Tory Island, on the north-west coast of Ireland, that crustacea, star-fish, and testacea, occurred at various depths between fifty and one hundred fathoms; and he drew up dentalia from the mud of Galway bay in 230 and 240 *fathoms* water.

The same hydrographer discovered on the Rockall bank large quantities of shells at depths varying from 45 to 190 fathoms. These shells were for the most part pulverized, and evidently recent, as they retained

their bright colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in eighty and ninety fathoms water. At the eastern extremity also of Rockall bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe Islands, usually at the depth of from forty to one hundred fathoms. In one part of this tract (long. 6° 30′, lat. 61° 50′) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some vertebræ being attached. This "bone bed," as it was called by our surveyors, is three miles and a half in length, and forty-five fathoms under water, and contains a few shells intermingled with the bones.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel; whereas, in the bed of the Adriatic, Donati found them frequently inclosed in stone of recent origin. This is precisely the difference in character which we might have expected to exist between the British marine formations now in progress, and those of the Adriatic; for calcareous and other mineral springs abound in the Mediterranean and lands adjoining, while they are almost entirely wanting in our own country.

During his survey of the west coast of Africa, Captain Belcher found, by frequent soundings between

the twenty-third and twentieth degrees of north latitude, that the bottom of the sea, at the depth of from twenty to about fifty fathoms, consists of sand with a great intermixture of shells, often entire, but sometimes finely comminuted. Between the eleventh and ninth degrees of north latitude, on the same coast, at soundings varying from twenty to about eighty fathoms, he brought up abundance of corals and shells mixed with sand. These also were in some parts entire, and in others worn and broken.

In all these cases, it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line of cliffs, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

But, although some deposits may thus extend continuously for a thousand miles or more near certain coasts, the greater part of the bed of the ocean, remote from continents and islands, may very probably receive, at the same time, no new accessions of drift matter, all sediment being intercepted by intervening hollows. Erroneous theories in geology may be formed not only from overlooking the great extent of simultaneous deposits now in progress, but also from the assumption that such formations may be universal or coextensive with the bed of the ocean.*

* See Book iv. chap. 3., where this subject is discussed more fully.

CHAPTER XVIII.

FORMATION OF CORAL REEFS.

Reefs not formed in deep sea—Composed partly of shells—Conversion of a reef into an island—Extent and thickness of coral formations — The Maldiva Isles — Rate of growth of coral — its geological importance — Circular and oval forms of coral islands (p. 306.) — Lagoons — causes of their peculiar configuration — Why the windward side higher than the leeward (p. 312.) — Stratification — That the subsidence by earthquakes in the Pacific exceeds the elevation — Henderson's Island — Coral on a high mountain in Otaheite (p. 318.)—Coral and shell limestones now in progress — The hypothesis that the quantity of calcareous matter has been and is still on the increase, considered.

The powers of the organic creation in modifying the form and structure of those parts of the earth's crust which may be said to be undergoing repair, or where new rock-formations are continually in progress, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean to the effects produced on a smaller scale upon the land, by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates while the lower portion is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In corals, in like manner, the more durable materials of the

generation that has passed away serve as the foundation on which living animals are continuing to rear a similar structure.

The stony part of the zoophyte may be likened to an internal skeleton; for it is surrounded by a soft animal substance capable of expanding itself, and when alarmed of contracting and drawing itself almost entirely into the hollows of the hard coral. Although oftentimes beautifully coloured in their own element, the soft parts become when taken from the sea nothing more in appearance than a brown slime spread over the stony nucleus.*

It was the opinion of the German naturalist Forster, in 1780, after his voyage round the world with Captain Cook, that coral animals had the power of building up steep and almost perpendicular walls from great depths in the sea, a notion afterwards adopted by Captain Flinders and others; but it is now very generally agreed that these zoophytes cannot live in water of great depths, and can only encrust the tops of submarine mountains with a calcareous covering a few fathoms thick.

These views have been confirmed by Ehrenberg, who has lately devoted more than a year to the examination of the corals of the Red Sea; but at the same time it must be remembered that strata of broken corals may accumulate to almost any thickness in the course of ages in the deep sea near the base of submarine mountains.

Composition of coral reefs. — The calcareous masses usually termed coral reefs are by no means exclusively

* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

the work of zoophytes; a great variety of shells, and, among them, some of the largest and heaviest of known species, contribute to augment the mass. In the south Pacific, great beds of oysters, mussels, *pinnæ marinæ*, and other shells, cover in profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and broken fragments of crustaceous animals. Large shoals of fish are also discernible through the clear blue water, and their teeth and hard palates are probably preserved, although a great portion of their soft cartilaginous bones decay.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the Lamarckian genera Meandrina, Caryophyllia, Madrepora, Porites, and Astrea, but especially the latter.

How converted into islands. — In the Pacific the reefs, which just raise themselves above the level of the sea, are usually of a circular or oval form, and surrounded by a deep and often unfathomable ocean. In the centre of each, there is usually a comparatively shallow lagoon, where there is still water, and on the borders of which, sometimes 100 fathoms deep, the smaller and more delicate kind of zoophytes find a tranquil abode, while the hardier species live on the exterior margin of the islet, where a great surf usually breaks. When the reef, says M. Chamisso, a naturalist who accompanied Kotzebue, is of such a height that it remains almost dry at low water, the corals leave off building. A continuous mass of solid stone is seen composed of the shells of molluscs and echini, with their broken-off prickles and fragments of coral, united by calcareous sand, produced by the pul-

verization of shells. Fragments of coral limestone are thrown up by the waves, until the ridge becomes so high that it is covered only during some seasons of the year by the high tides. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places. The force of the waves is thereby enabled to separate and lifts blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef. "After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting place after their long wanderings: with these come some small animals, such as lizards and insects, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take refuge in the bushes; and, at a much later period, when the work has been long since completed, man appears, and builds his hut on the fruitful soil." *

In the above description the solid stone is stated to consist of shell and coral united by sand; but masses of very compact limestone are also found even in the uppermost and newest parts of the reefs, such as could only have been produced by chemical precipitation. It is suggested that in these instances the carbonate of lime may have been derived from the decomposition of corals and testacea; for when the animal matter undergoes putrefaction, the calcareous residuum must be set free under circumstances very favourable to pre-

* Kotzebue's Voyages, 1815–18, vol. iii. pp. 331—333.

cipitation, especially when there are other calcareous substances, such as shells and corals, on which it may be deposited. Thus organic bodies may be inclosed in a solid cement, and become portions of rocky masses.*

Lieutenant Nelson states that in the Bermuda islands the reefs assume the form of the bottom of the sea, on which they rest; and among every variety of configuration it happens here and there that zones of coral inclose tranquil basins, within which the decomposition of numerous zoophytes produces a soft white calcareous mud resembling chalk. Some of this dried mud, now in the museum of the Geological Society, is not distinguishable from some of the common soft chalk of England. In the same islands, also, several varieties of compact limestone are formed. Amongst other fossil bodies inclosed in the coral sandstones of this group are marine and terrestrial shells, corals, the hard parts of crabs, and the bones of birds.†

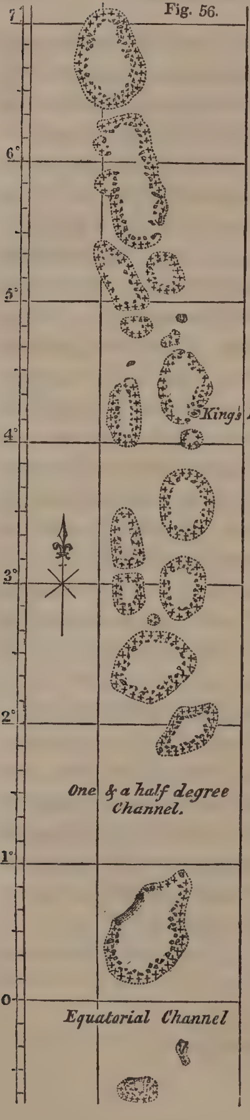
Extent and thickness.—The Pacific Ocean, throughout a space comprehended between the thirtieth parallel of latitude on each side of the equator, is extremely productive of coral; as also are the Arabian and Persian Gulfs. Coral is also abundant in the sea between the coast of Malabar and the island of Madagascar. Flinders describes an unbroken reef, 350 miles in length, on the east coast of New Holland; and, between that country and New Guinea, Captain P. King found the coral formations to extend throughout a distance of 700 miles, interrupted by no intervals exceeding thirty miles in length.

Maldiva Isles.—The chain of coral reefs and islets

* Stutchbury, West of Eng. Journ., No. 1., p. 50.

† Proceedings of Geol. Soc., No. 36., p. 81.

Fig. 56.



called the Maldivas, situated in the Indian Ocean, to the south-west of Malabar, form a chain 480 geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, the larger groups being from forty to fifty miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, informs me, that outside of each circle or atoll, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to twenty fathoms deep. In the channels between the atolls, no soundings have been obtained at the depth of 150 fathoms.

Laccadive Islands.— The Laccadive islands run in the same line with the Maldivas, on the north, as do the isles of the Chagos Archipelago, on the south; so that these may be continuations of the

same chain of submarine mountains, crested in a similar manner by coral limestones. Possibly they may all be the summits of volcanos; for, if Java and Sumatra were submerged, they would give rise to a somewhat similar shape in the bottom of the sea; since the volcanos of those islands observe a linear direction, and are often separated from each other by intervals, corresponding to those between the atolls of the Maldivas; and as they rise to various heights, from five to ten thousand feet above their base, they might leave an unfathomable ocean in the intermediate spaces.

In regard to the thickness of the masses of coral, MM. Quoy and Gaimard are of opinion, that the species which contribute most actively to the formation of solid masses do not grow where the water is deeper than twenty-five or thirty feet; but other competent observers declare that they reach to the depth of ninety feet, and even more.* The branched madrepores live at the greatest depths, and may form the first foundation of a reef, and raise a platform on which other species may build.†

Rate of the growth of coral. — The rapidity of the growth of coral is by no means great, according to the report of the natives to Captain Beechey. In an island west of Gambier's group, our navigators observed the *Chama gigas* (Tridacna, Lam.), while the animal was yet living, so completely overgrown by coral, that a space only of two inches was left for the extremity of the shell to open and shut.‡ But conchologists suppose that the chama may require thirty

* Stutchbury, West of England Journ., No. 1. p. 47.

† Journ. of Roy. Geograph. Soc. of London, 1831, p. 218.

‡ Beechey's Voyage to the Pacific, &c., p. 157.

years or more to attain its full size, so that the fact is quite consistent with a very slow rate of increase in the calcareous reefs.

At the island called Taaopoto, in the South Pacific, the anchor of a ship wrecked about fifty years before was observed in seven fathom water still preserving its original form, but entirely encrusted by coral.* An oyster, which cannot have been more than two years old when taken, is preserved in the museum of the Bristol Institution, enveloped by a dense coral, a species of *Agaricia*, weighing 2 lb. 9 oz.†

In Captain Beechey's late expedition to the Pacific, no positive information could be obtained of any channel having been filled up within a given period; and it seems established, that several reefs had remained, for more than half a century, at about the same depth from the surface.

Ehrenberg also questions the fact of channels and harbours having been closed up in the Red Sea by the rapid increase of coral limestone. He supposes the notion to have arisen from the circumstance of havens having been occasionally filled up in some places with coral sand, in others with large quantities of ballast of coral rock thrown down from vessels. The same observer saw single corals of the genera Meandrina and Favia, having a globular form, from six to nine feet in diameter, which he imagines to be of immense antiquity, so that Pharaoh, he thinks, may have looked upon these same individuals in the Red Sea.‡

They certainly prove, as he remarks, that the reef on which they grow has increased at a very slow rate. After collecting more than 100 species, he found none

* Stutchbury, West of England Journ., No. 1. p. 49.

† Ibid., p. 51. ‡ Ehrenberg, as before cited, p. 41.

of them covered with parasitic zoophytes, nor any instance of a living coral growing on another living coral. To this repulsive power which they exert whilst living against all others of their own class, we owe the beautiful symmetry of some large Meandrinæ and other species which adorn our museums. Yet balani and serpulæ can attach themselves to corals, and holes are excavated in them by saxicavous mollusca.* The natives of the Bermuda Islands point out certain corals now growing in the sea, which, according to tradition, have been living in the same spots for centuries. It is supposed that they may vie in age with the most ancient trees of Europe.

But, when we admit the increase of coral limestone to be slow, we are merely speaking with relation to the periods of human observation. It often happens that parasitic testacea live and die on the shells of the larger slow-moving gasteropods in the South Seas, and become entirely inclosed in an incrustation of compact limestone, while the animal, to whose habitation they are attached, crawls about, and bears upon his back these shells, which may be considered as already fossilized. It is, therefore, probable, that the reefs increase as fast as is compatible with the thriving state of the organic beings which chiefly contribute to their formation ; and, if the rate of augmentation thus implied be called, in conformity to our ordinary ideas of time, gradual and slow, it does not diminish, in the least degree, the geological importance of such calcareous masses.

Suppose the ordinary growth of coral limestone to amount to six inches in a century, it will then require

* Ehrenberg, as above cited, p. 42.

3,000 years to produce a reef fifteen feet thick: but have we any ground for presuming, that, at the end of that period, or of ten times thirty centuries, there will be a failure in the supply of lime, or that the polyps and molluscs will cease to act, or that the hour of the dissolution of our planet will first arrive, as the earlier geologists were fain to anticipate?

Instead of contemplating the brief annals of human events, let us turn to some natural chronometers; to the volcanic isles of the Pacific, for example, which shoot up 10,000 feet or more above the level of the ocean. These islands bear evident marks of having been produced by successive volcanic eruptions; and coral reefs are sometimes found on the volcanic soil, reaching for some distance from the sea-shore into the interior. When we consider the time required for the accumulation of such mountain masses of igneous matter, according to the analogy of known volcanic agency, all idea of extenuating the comparative magnitude of coral limestones, on the ground of the slowness of the operations of lithogenous polyps, must instantly vanish.

Form of coral islands. — The information collected during the late expedition to the Pacific, throws much additional light on the peculiarities of form and structure of coral islands. Of thirty-two of these, examined by Captain Beechey, the largest was thirty miles in diameter, and the smallest less than a mile. They were of various shapes, all formed of living coral, except one, which, although of coral formation, was raised about eighty feet above the level of the sea, and encompassed by a reef of living coral. * All were increasing their dimensions by the active operations

* This islet is called Henderson's, see p. 316.

of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. Twenty-nine of the number had lagoons in their centres, which had probably existed in the others, until they were filled, in the course of time, by zoophytic and other substances.

In the above-mentioned islands, the strips of dry coral encircling the lagoons, when divested of loose sandy materials heaped upon them, are rarely elevated more than two feet above the level of the sea; and, were it not for the abrupt descent of the external margin which causes the sea to break upon it, these strips would be wholly inundated. Those parts of the strip which are beyond the reach of the waves are no longer inhabited by the animals that reared them, but have their cells filled with a hard calcareous substance, and present a brown rugged appearance. The parts which are still immersed, or which are dry only at low water, are intersected by small channels, and are so full of hollows, that the tide, as it recedes, leaves small lakes of water upon them. The width of the plain, or strip of dead coral, in the islands which fell under Captain Beechey's observation, in no instance exceeded half a mile from the usual wash of the sea to the edge of the lagoon, and, in general, was only about three or four hundred yards.* Beyond these limits the sides of the island descend rapidly, apparently by a succession of inclined ledges, each terminating in a precipice. The depth of the lagoons is various; in some, entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

Whitsunday Island. — In the annexed cut (Fig. 57.),

* Captain Beechey, part i. p. 188.

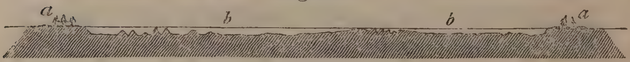
one of these circular islands is represented just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within a lagoon of tranquil water.

Fig. 57.

*View of Whitsunday Island.**

Sections of coral isles. — The accompanying section will enable the reader to comprehend the usual form of such islands. (Fig. 58.)

Fig. 58.



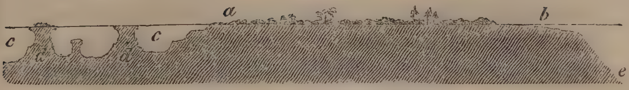
Section of a Coral Island.

a a. Habitable part of the island, consisting of a strip of coral, inclosing the lagoon. *b b*. The lagoon.

The subjoined cut (Fig. 59.) exhibits a small part of the section of a coral island on a larger scale.

* This plate and the section which follows are copied, by permission of Captain Beechey, from the illustrations of his valuable work before alluded to.

Fig. 59.



Section of part of a Coral Island.

a b. Habitable part of the island.
b e. Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
c c. Part of the lagoon.
d d. Knolls of coral in the lagoon, with overhanging masses of coral, resembling the capitals of columns.

Origin of their peculiar configuration.—The circular or oval forms of the numerous coral isles of the Pacific, with the lagoons in their centre, naturally suggest the idea that they are nothing more than the crests of submarine volcanos, having the rims and bottoms of their craters overgrown by coral. This opinion is strengthened by the conical form of the submarine mountain, and the steep angle at which it plunges on all sides into the surrounding ocean. It is also well known that the Pacific is a great theatre of volcanic action, and every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones.

It has also been observed that although, within the circular coral reefs, there is usually nothing discernible but a lagoon, the bottom of which is covered with coral, yet within some of these basins, as in Gambier's group, rocks composed of porous lava, and other volcanic substances, rise up, resembling the two Kamenis and other eminences of igneous origin, which have been thrown up within the times of history, in the midst of the Gulf of Santorin.*

* See Vol. II. p. 208.

It has been mentioned that, in volcanic archipelagos there is generally one large habitual vent, and many smaller volcanos formed at different points and at irregular intervals, all of which have usually a linear arrangement. Now, in several of the groups of Eastern Oceanica there appears to be a similar disposition; the great islands, such as Otaheite, Owhyhee, and Terra del Spirito Santo, being habitual vents, and the lines of small circular coral isles, which are dependent on them, being very probably trains of minor volcanos, which may have been in eruption singly and at irregular intervals.

The absence of circular groups in the West Indian seas, and the tropical parts of the Atlantic, where corals are numerous, has been adduced as an additional argument, inasmuch as volcanic vents, though existing in those regions, are very inferior in importance to those in the Pacific and Indian oceans.* We are also informed by Ehrenberg, that all the banks of coral in the Red Sea, some of which are square, but most of them ribbon-like strips, have flat summits, and are without lagoons; a fact which seems to demonstrate that the stonemaking zoophytes do not of themselves build circular islets with a central cup-shaped cavity. It may be objected that the circles formed by some coral reefs or groups of coral islets, varying as they do from ten to thirty miles and upwards in diameter, are so great as to preclude the idea of their being volcanic craters. In regard to this objection, I may refer to what I have said in a former volume respecting the size of the so-called craters of elevation, many of which are, probably, the ruins of truncated cones.†

* De la Beche, Geol. Man., p. 141. first ed.

† See Vol. II. p. 216.

Openings into the lagoons.—There is yet another phenomenon attending the circular reefs, to which I have not alluded, viz., the deep narrow passage which almost invariably leads from the sea into the lagoon, and is kept open by the efflux of the sea at low tides. It is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide, and, when the sea falls, to rush out violently at one or more points where the reef happens to be lowest or weakest. At first there are probably many openings; but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge; so that their number is gradually reduced to a few, and often finally to one. This event is strictly analogous to that witnessed in our estuaries, where a body of salt water accumulated during the flow issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river.

In controverting Von Buch's theory of "elevation craters," I mentioned, that a single deep gorge is described as always connecting the central cavity of such craters with the sea. The origin of this channel may be sought in the action of the tides, which may, in many cases, afford a satisfactory explanation. Suppose a volcanic cone, having a deep crater, to be at at first submarine, and to be then *gradually* elevated by earthquakes in an ocean where tides prevail, a ravine may be cut like that which penetrates into the Caldera of the isle of Palma. The opening would at first be made on that side where the rim of the crater was originally lowest, and it would afterwards be deepened as the

island rose, so as always to descend somewhat lower than the level of the sea.

In the coral reefs surrounding those volcanic islands in the Pacific, which are large enough to feed small rivers, there is generally an opening or channel opposite the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds twenty-five feet; and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations.*

Why the windward side highest.—But there is yet another peculiarity of the low coral islands in the Pacific, the explanation of which is by no means so obvious. They follow one general rule in having their windward side higher and more perfect than the other. "At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water; where, however, they may be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the direction of the wind, as at Bow Island, yet there are none to windward." These observations of Captain Beechey accord perfectly with those first made by Flinders on the Australian reefs, and which Captain Horsburgh, and other hydrographers, have made in regard to the coral islands of other seas. Thus the Chagos Isles in the Indian Ocean are chiefly of a horseshoe form, the openings being to the northwest; whereas

* Voyage to the Pacific, &c., p. 194.

the prevailing wind blows regularly from the south-east. From this fortunate circumstance ships can enter and sail out again with ease; whereas, if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours depends entirely on this fortunate peculiarity in their structure.

In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there is a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side.*

I am informed by Captain King, that, on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits

* Voyage to the Pacific, &c., p. 189.

of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But, the difficulty will, perhaps, be removed, if we call in another part of the volcanic agency — subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition of such operations, by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy), might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef; while the action of the breakers contributes to raise the windward barrier.

In the Red Sea the banks of coral are, for the most part, only seen when the tide is out. Neither in the submerged banks, nor in such coral islets as are slightly elevated above the sea, is the windward side higher than the leeward, or that which is towards the coast, and protected from the breakers. The prevailing wind there is from the north.*

Stratification of coral formations.— The calcareous formations of the Pacific are probably all stratified, although single beds may sometimes attain a great thickness. The occasional drifting of sand from the exposed parts of a reef into the lagoon or the sur-

* Ehrenberg, as before cited, p. 29.

rounding sea, would suffice to form occasional lines of partition, especially during violent tempests, which occur annually among the South Sea Islands. The decomposition of felspathic lavas may supply the current which washes and undermines the cliffs of some islands with fine clay; and this may be carried to great distances and deposited in distinct layers between calcareous masses, or may be mingled with them and form argillaceous limestones. Other divisions will arise from the arrangement of different species of testacea and zoophytes, which inhabit water of various depths, and which succeed each other as the sea is deepened by the fall of its bed during earthquakes, or in proportion as it grows shallower by elevation due to the same cause, or by the accumulation of organic substances raising the bottom.

To these causes of minor subdivision must be added another of great importance — the ejection of volcanic ashes and sand, often carried by the wind over wide areas, and the flowing of horizontal sheets of lava, which may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the Isle of France, where a bed of coral, ten feet thick, intervenes between two currents of lava*; and in the West Indies, in the island of Dominica, Maclure observes, that "a bed of coral and madrepore limestone, with shells, lies horizontally on a bed of cinders, about two or three hundred feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height."†

* De la Beche, Geol. Man., p. 142. Quoy and Gaimard, Ann. des Sci. Nat., tome vi.

† Observ. on Geology of the West Indian Islands, Journ. of Sci., &c., No. x. p. 318.

Reefs in the Pacific. — The sunken reefs in the Pacific are sometimes of such extent that a series of ordinary earthquakes might, in the course of a few centuries, convert large tracts of them into dry land. It is therefore a remarkable circumstance that there should be so vast an area in Eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belongs to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

Suppose the shoal, above described as 600 miles in length, to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case, the new coral formed since the first subsidence will constitute an island 600 miles long. An analogous result would have occurred if a lava-current fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific seems to show that the amount of subsidence by earthquakes exceeds, in that quarter of the globe, at present the elevation due to the same cause.

Elizabeth, or Henderson's Island. — I mentioned that one of the thirty-two islands, examined by our navigators in the late expedition, was raised about

eighty feet above the level of the sea.* It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and, on all sides, except the north, is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honey-combed at the surface, and hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those which are less injured in this

Fig. 60.

Elizabeth or Henderson's Island.

way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods; but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion.†

At the distance of a few hundred yards from this island, no bottom could be gained with 200 fathoms of line. It will be seen, from the annexed sketch, communicated to me by Lieutenant Smith, of the Blossom, that the trees come down to the beach towards the centre of the island; a break which at

* According to some accounts, between sixty and seventy feet.

† Beechey's Voyage to the Pacific, &c., p. 46.

first sight resembles the openings which usually lead into lagoons: but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived. The reader will remark, that such a mass of limestone represents exactly those horizontal cappings of calcareous strata which we sometimes find on hills which have tabular summits.

As earthquakes are now felt from time to time in this part of the Pacific, and as indications of very recent changes of level are not wanting *, the era of the elevation of Henderson's Island may not be very remote.

We are informed by Mr. Stutchbury, that upon the summit of nearly the highest mountain in Tahiti (or Otaheite), an island composed almost entirely of volcanic rocks, there is a distinct stratum of fossil coral, showing that a great part, if not the whole, island has been raised from the sea, and does not consist merely of lava and scoriæ, thrown out by supramarine eruptions. Whether the species of coral were identical with those now living, or what was the exact height of the coral, was unfortunately not ascertained; for Mr. Stutchbury did not visit the spot, though he saw some masses of the limestone which had fallen from the high mountain, and which appeared to him to resemble the coral of modern reefs. He supposed that the altitude of the highest peak in Otaheite was 12,000 feet, and that of the coral not greatly inferior; but Captain Beechey informs me, that the peak is not quite 7000 feet high, as he found, by the mean of three observations, carefully taken with the sextant. Mr. Stutchbury suggests that "as a great reef, or platform

* See Captain Beechey's Voyage to the Pacific, &c., pp. 159. and 191.

of coral, surrounds the actual shores of Otaheite, the island, had it been raised out of the sea gradually, or by a succession of movements, must have been everywhere coated over with a covering of coral; and as this is not the case, no coral having yet been seen in the interior, except on the mountain above mentioned, Otaheite must have been projected suddenly to its present height by a single upthrow."*

Before we adopt so important a conclusion we must, in the first place, remember that the surface of a small part only of the island has been carefully explored by naturalists, and, what is far more to the point, we have yet to learn whether some craters in Otaheite may not have been in eruption subsequently to the emergence of the island. At a much lower elevation than the coral, Mr. Stutchbury states that there is an extinct volcanic crater, having at its bottom a lake, about a mile in diameter; a fact also mentioned by Captain Beechey and others. Now in the volcanic island of Ischia, in the neighbourhood of Naples, some of the tuffs near the highest peak contain marine shells, similar to those now living in the Mediterranean; so that these tuffs were evidently submarine deposits. Consequently Ischia has, like Otaheite, been raised to its present height above the level of the sea by a movement from below. But we know, partly by historical and partly by geological evidence, that many of the Ischian cones and craters have been in eruption since it emerged; and during these eruptions its surface has been overspread with so dense a coating of lava and scoriæ, that it has now become impossible to determine whether the land rose suddenly or slowly, or what was

* Stutchbury, West of Eng. Journ., No. 1., p. 55.

the state of its surface when it first emerged. The same observations apply to Otaheite.

Vast area of coral formations. — The calcareous masses above considered constitute, together with the associated volcanic formations, the most extensive of the groups of rocks which can be demonstrated to be now in progress. The space in the sea which they occupy is so vast, that we may safely infer that they exceed in area any group of ancient rocks which can be proved to have been of contemporaneous origin. It is true that each of the great archipelagos of the Pacific are separated by unfathomable abysses, where no zoophytes may live, and no lavas flow; where not even a particle of coral sand or volcanic scoriæ may be drifted: but still, if we confine our view to the extent of reef ascertained to exist, and assume that a certain space around each volcanic or coral isle has been covered with ejections, or matter from the waste of cliffs, it will then be seen that the space occupied by these formations may equal, and perhaps exceed in area, that part of our continents which has been accurately explored by geologists.

That the increase of these calcareous masses should be principally, if not entirely, confined to the shallower parts of the ocean, or, in other words, to the summits of submarine ranges of mountains and elevated platforms, is a circumstance of the highest interest to the geologist; for if parts of the bed of such an ocean should be upraised, so as to form large continents, mountain-chains might appear, capped and flanked by calcareous strata of great thickness, and replete with organic remains; while in the intervening lower regions no rocks of contemporary origin would ever have existed.

Lime, whence derived. — A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary; and this may have some connexion with the rarity of testaceous animals in the ancient ocean. He further infers, that, in consequence of the operations of animals, "the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that, as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata." *

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem the speculation improbable; but, when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, I can discover no sufficient grounds for such an hypothesis, and many facts which militate against it.

If a large pond be made, in almost any soil, and filled with rain water, it may usually become tenanted by testaçea; for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds, or by springs, no tufa or shell-marl are

* Macculloch's Syst. of Geol., vol. i. p. 219.

formed. The thin shells of one generation of molluscs decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl have been the sites of springs, which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Lock Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of calcareous matter in their stems to abound near springs impregnated with carbonate of lime. We know that, if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents; and some birds eat chalk greedily during the breeding season.

If, on the other hand, we turn to the phenomena of inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, either free, in a gaseous form, or mixed with water; and the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map recently constructed by Targioni, to show the principal sites of mineral springs, can doubt, for a moment, that if this territory was submerged beneath the sea, it might supply materials for the most extensive coral

reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea; and a geologist might as well assume the mass of alluvium formed in a few years in the bed of the Po, or the Ganges, to be the measure of the quantity deposited in the course of centuries in the deltas of those rivers, as conceive that the influence of the carbonated springs in Italy can be estimated by the mass of tufa precipitated by them near their sources.

It is generally admitted that the abundance of carbonate of lime given out by springs, in regions where volcanic eruptions or earthquakes prevail, is referrible to the solvent power of carbonic acid. For, as the acidulous waters percolate calcareous strata, they take up a certain portion of lime and carry it up to the surface, where, under diminished pressure in the atmosphere, it may be deposited, or, being absorbed by animals and vegetables, may be secreted by them. In Auvergne, springs charged with carbonate of lime rise through granite, in which case we must suppose the calcareous matter to be derived from some primary rock, unless we imagine it to rise up from the volcanic foci themselves.

We see no reason for supposing that the lime now on the surface, or in the crust of the earth, may not, as well as the silex, alumine, or any other mineral substance, have existed before the first organic beings were created, if it be assumed that the arrangement of the inorganic materials of our planet preceded in

the order of time the introduction of the first organic inhabitants.

But if the carbonate of lime, secreted by the testacea and corals of the Pacific, be chiefly derived *from below*, and if it be a very general effect of the action of subterranean heat to subtract calcareous matter from the *inferior* rocks, and to cause it to ascend to the surface, no argument can be derived in favour of the progressive increase of limestone from the magnitude of coral reefs, or the greater proportion of calcareous strata, in the more modern formations. A constant transfer of carbonate of lime from the inferior parts of the earth's crust to its surface, would cause throughout all future time, and for an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer, as contrasted with the older formations.

BOOK IV.

CHAPTER I.

PRELIMINARY OBSERVATIONS.

System of inquiry into the causes of geological phenomena as adopted in this work, how differing from that of many preceding writers — Illustrations from the history of Geology of the respective merits of the two systems — Reasons for prefixing to a work on Geology treatises respecting the changes now in progress in the animate and inanimate world.

Having considered, in the preceding books, the actual operation of the causes of change which affect the earth's surface and its inhabitants, we are now about to enter upon a new division of our inquiry, and it may be useful to offer a few preliminary observations, to establish the connexion between two distinct parts of this work, and to explain in what manner its plan differs from that usually followed by preceding writers on Geology.

All naturalists who have carefully examined the arrangement of the mineral masses composing the earth's crust, and who have studied their internal structure and fossil contents, have recognized therein the signs of a great succession of former changes; and the causes of these changes have been the object of anxious inquiry. As the first theorists possessed but a scanty acquaintance with the present economy of the animate and inanimate world, and the vicissitudes to which these are subject, we find them in the situation of novices, who attempt to read a history

written in a foreign language, doubting about the meaning of the most ordinary terms; disputing, for example, whether a shell was really a shell,—whether sand and pebbles were the result of aqueous trituration,—whether stratification was the effect of successive deposition from water; and a thousand other elementary questions, which now appear to us so easy and simple, that we can hardly conceive them to have once afforded matter for warm and tedious controversy.

In the first book were enumerated many of the prepossessions which may have biassed the minds of the earlier inquirers, and checked an impartial desire of arriving at truth. But of all the causes alluded to, no one contributed so powerfully to give rise to a false method of philosophizing, as the entire unconsciousness of the first geologists of the extent of their own ignorance respecting the operations of the existing agents of change.

They imagined themselves sufficiently acquainted with the mutations now in progress in the animate and inanimate world, to entitle them at once to determine, whether the solution of certain problems in geology could ever be derived from the observation of the actual economy of nature; and, having decided that they could not, they felt themselves at liberty to indulge their imaginations, in guessing at what *might be*, rather than in inquiring *what is;* in other words, they employed themselves in conjecturing what might have been the course of nature at a remote period, rather than in the investigation of what was the course of nature in their own times.

It appeared to them more philosophical to speculate on the possibilities of the past, than patiently to ex-

plore the realities of the present; and having invented theories under the influence of such maxims, they were consistently unwilling to test their validity by the criterion of their accordance with the ordinary operations of nature. On the contrary, the claims of each new hypothesis to credibility appeared enhanced by the great contrast of the causes or forces introduced to those now developed in our terrestrial system during a period, as it has been termed, of *repose.*

Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change. It produced a state of mind unfavourable in the highest degree to the candid reception of the evidence of those minute but incessant alterations which every part of the earth's surface is undergoing, and by which the condition of its living inhabitants is continually made to vary. The student, instead of being encouraged with the hope of interpreting the enigmas presented to him in the earth's structure, — instead of being prompted to undertake laborious inquiries into the natural history of the organic world, and the complicated effects of the igneous and aqueous causes now in operation, was taught to despond from the first. Geology, it was affirmed, could never rise to the rank of an exact science, — the greater number of phenomena must for ever remain inexplicable, or only be partially elucidated by ingenious conjectures. Even the mystery which invested the subject was said to constitute one of its principal charms, affording, as it did, full scope to the fancy to indulge in a boundless field of speculation.

The course directly opposed to these theoretical views consists in an earnest and patient endeavour to reconcile the former indications of change with the evidence of gradual mutations now in progress; restricting us, in the first instance, to known causes, and then speculating on those which may be in activity in regions inaccessible to us. It seeks an interpretation of geological monuments, by comparing the changes of which they give evidence with the vicissitudes now in progress, or *which may be* in progress.

I shall give a few examples in illustration of the practical results already derived from the two distinct methods of theorizing; for we have now the advantage of being enabled to judge of their respective merits, by the relative value of the fruits which they have produced.

From the historical sketch before given of the progress of geology, the reader has seen that a controversy was maintained for more than a century respecting the origin of fossil shells and bones — were they organic or inorganic substances? That the latter opinion should for a long time have prevailed, and that these bodies should have been supposed to be fashioned into their present form by a plastic virtue, or some other mysterious agency, may appear absurd; but it was, perhaps, as reasonable a conjecture as could be expected from those who did not appeal, in the first instance, to the analogy of the living creation, as affording the only source of authentic information. It was only by an accurate examination of living testacea, and by a comparison of the osteology of the existing vertebrated animals with the remains found entombed in ancient strata, that this favourite dogma was exploded, and all were, at length, persuaded that these substances were exclusively of organic origin.

In like manner, when a discussion had arisen as to the nature of basalt and other mineral masses, evidently constituting a particular class of rocks, the popular opinion inclined to a belief that they were of aqueous, not of igneous origin. These rocks, it was said, might have been precipitated from an aqueous solution, from a chaotic fluid, or an ocean which rose over the continents, charged with the requisite mineral ingredients. Few will now dispute that it would have been difficult to invent a theory more distant from the truth; yet we must cease to wonder that it gained so many proselytes, when we remember that its claims to probability arose partly from the very circumstance of its confirming the assumed want of all analogy between geological causes and those now in action.

By what train of investigation were all theorists brought round, at length, to an opposite opinion, and induced to assent to the igneous origin of these formations? By an examination of the structure of active volcanos, the mineral composition of their lavas and ejections, and by comparing the undoubted products of fire with the ancient rocks in question.

I shall adduce one more example. When the organic origin of fossil shells had been conceded, their occurrence in strata forming some of the loftiest mountains in the world was admitted as a proof of a great alteration of the relative level of sea and land; and the question then arose, whether this change was to be accounted for by the partial drying up of the ocean, or by the elevation of the solid land. The former hypothesis, although afterwards abandoned by general consent, was at first embraced by a vast majority. A multitude of ingenious speculations were hazarded, to show how the level of the ocean might have been

depressed; and when these theories had all failed, the inquiry, as to what vicissitudes of this nature might now be taking place, was, as usual, resorted to in the last instance. On inquiring, whether any changes in the level of sea and land had occurred during the historical period, it was soon discovered, by patient research, that considerable tracts of land had been permanently elevated and depressed, while the level of the ocean remained unaltered. It was therefore necessary to reverse the doctrine which had acquired so much popularity; and the unexpected solution of a problem at first regarded as so enigmatical gave, perhaps, the strongest stimulus ever yet afforded to investigate the ordinary operations of nature.

Of late years, the points of discussion in geology have been transferred to new questions, and those, for the most part, of a higher and more general nature. We are now nearly agreed as to what rocks are of igneous, and what of aqueous origin,—in what manner fossil shells, whether of the sea or of lakes, have been imbedded in strata,—how sand may have been converted into sandstone,—and are unanimous as to many other propositions which are not of a complicated nature; but when we ascend to those of a higher order, we are still too often reluctant to make a strenuous effort, in the first instance, to search out an explanation in the ordinary economy of Nature. If, for example, we seek for the causes why mineral masses are associated together in certain groups; why they are arranged in a certain order, which is never inverted; why there are many breaks in the continuity of the series; why different organic remains are found in distinct sets of strata; why there is often an abrupt passage from an assemblage of species contained in

one formation to that in another immediately superimposed,—when these, and other topics of an equally extensive kind are discussed, we often find the habit of indulging conjectures, respecting irregular and extraordinary causes, to be still in force.

We hear of sudden and violent revolutions of the globe—of the instantaneous elevation of mountain chains—of paroxysms of volcanic energy, declining, according to some, and, according to others, increasing in violence, from the earliest to the latest ages. We are also told of general catastrophes, and a succession of deluges—of the alternation of periods of repose and disorder—of the refrigeration of the primitive heated nucleus of the globe—of the sudden annihilation of whole races of animals and plants—and other hypotheses, in which we see the ancient spirit of speculation revived, and a desire manifestly shown to cut, rather than patiently to untie, the Gordian knot.

In the following attempt to unravel these difficult questions, I shall endeavour, as far as possible, to restrict myself to the known or possible operations of existing causes; feeling assured that we have not yet exhausted the resources which the study of the present course of nature may provide, and therefore that we are not authorized, in the infancy of our science, to recur to extraordinary agents. I shall adhere to this plan, not only on the grounds explained in the first book; but because, as I have just stated, the history of the science informs us that this method has always put geologists on the road that leads to truth—suggesting views which, although imperfect at first, have been found capable of improvement, until at last adopted by universal consent. On the other hand, the opposite

method, that of speculating on a former distinct state of things, has led invariably to a multitude of contradictory systems, which have been overthrown one after the other,—which have been found quite incapable of modification,—and which are often required to be precisely reversed.

In regard to the subjects treated of in the last two books,—the recent changes of the organic and inorganic world,—they may be said to constitute the alphabet and grammar of geology. If I had found systematic treatises previously written on these topics, I should willingly have entered at once upon the description of geological monuments properly so called: in which case, I should have referred to other authors for the elucidation of elementary and collateral questions, just as I shall now appeal to the best authorities in conchology and comparative anatomy for the proof of positions which, but for the labours of naturalists devoted to those departments, would have demanded long digressions.

CHAPTER II.

GENERAL ARRANGEMENT OF THE MATERIALS COMPOSING THE EARTH'S CRUST.

The existing continents chiefly composed of subaqueous deposits — Distinction between sedimentary and volcanic rocks — Between primary, secondary, and tertiary — Origin of the rocks usually termed primary — Transition formations (p. 340.) — Secondary and tertiary strata — Chronological relations of mineral masses — Laws of superposition — Relative age proved by included fragments of older rocks — Proofs of contemporaneous origin derived from mineral characters — from organic remains (p. 347.) — Zoological provinces of limited extent — Modes whereby dissimilar mineral masses and distinct groups of species may be proved to have been contemporaneous.

When we examine into the structure of the earth's crust, or that small portion of the exterior of our planet accessible to human observation, whether we pursue our inquiries by aid of mining operations, or by observing the sections laid open in the sea cliffs, or in the deep ravines of mountainous countries, we discover everywhere a series of mineral masses, which are not thrown together in a confused heap, but arranged with considerable order; and even where their original position has undergone great subsequent disturbance, there still remain proofs of the order that once reigned.

If we drain a lake, we frequently find at the bottom

a series of recent deposits disposed with great regularity one above the other; the uppermost, perhaps, may be a stratum of peat, next below a more compact variety of the same material, still lower a bed of laminated shell marl alternating with peat, and then other beds of marl divided by layers of clay. Now if a second pit be sunk through the same continuous lacustrine deposit, at some distance from the first, we commonly meet with nearly the same series of beds, yet with slight variations; some, for example, of the layers of sand, clay, or marl may be wanting, one or more of them having thinned out and given place to others, or sometimes one of the masses, first examined, is observed to increase in thickness to the exclusion of other beds. At length we reach a point where the whole assemblage of lacustrine strata terminate, as for example when we arrive at the borders of the original lake-basin. Here the beds come in contact with the rocks which form the boundary of, and, at the same time, pass under all the recent accumulations.

In almost every estuary, we may observe at low water phenomena analogous to those of lakes, where the current has cut away part of some newly formed bank, consisting of a series of horizontal strata of peat, sand, clay, and, sometimes, interposed beds of shells. Each of these may often be traced over a considerable area, some extending farther than others, but all of necessity confined within the basin of the estuary. Similar remarks are applicable, on a much more extended scale, to the recent deltas of great rivers, like the Ganges, where, after the periodical inundations have subsided, sections are exposed in the river-banks and cliffs of numerous islands, in which horizontal beds of clay and sand may be traced over areas many

hundred miles in length, and more than a hundred in breadth.

Subaqueous deposits. — The greater part of our continents are evidently composed of subaqueous deposits; and in the manner of their arrangement we discover many characters precisely similar to those above described; but the different groups of strata are, for the most part, on a greater scale, both in regard to depth and area, than any observable in the formations of lakes, deltas, or estuaries. We find, for example, masses of limestone several hundred feet in thickness, containing corals and shells, and stretching from one country to another; yet always giving place, at length, to a distinct set of strata, which either rise up from beneath like the rocks before alluded to as forming the boundary of a lake, or cover and conceal them. In other places, we find beds of pebbles and sand, or of clay, of great thickness. The different formations composed of these materials usually contain some peculiar and appropriate organic remains; as, for example, certain species of shells and corals, or certain plants.

Volcanic rocks. — Besides these strata of aqueous origin, we find other rocks which are immediately recognized to be the products of fire, from their exact resemblance to those which have been produced in modern times by volcanos, and thus we immediately establish two distinct orders of mineral masses composing the crust of the globe — the sedimentary and the volcanic.

Rocks commonly called primary. — But if we examine a large portion of a continent which contains within it a lofty mountain range, we rarely fail to discover another class of rocks very distinct from either

of those above alluded to, and which we can assimilate neither to deposits such as are now accumulated in lakes or seas, nor to those generated by ordinary volcanic action. This class consists of granite, granitic schist, roofing slate, and many other rocks, of a much more compact and crystalline texture than the sedimentary and volcanic divisions before mentioned. In the unstratified portion of these crystalline masses, as in the granite, for example, no organic fossil remains have ever been discovered, and only a few faint traces of them in some of the *stratified* groups of the same class; for I may remark, that a considerable portion of these rocks are divided, not only into strata, but into laminæ, so closely imitating the internal arrangement of well-known aqueous deposits, as to leave scarcely any reasonable doubt that they owe this part of their texture to similar causes.

These remarkable formations have been called *primitive*, from their having been supposed to constitute the most ancient mineral productions of the globe, and from a notion that they originated before the earth was inhabited by living beings, and while yet the planet was in a nascent state. The high relative antiquity of some of them is indisputable; for in the oldest sedimentary strata, containing organic remains, we often meet with rounded pebbles of the crystalline rocks, which must therefore have been consolidated before the derivative strata were formed out of their ruins. The members of this granitic group generally rise up from beneath the rocks of mechanical origin, entering into the structure of lofty mountains, so as to occupy, at the same time, the lowest and most elevated position in the crust of the globe.

Origin of rocks called primary. — Nothing strictly

analogous to these crystalline formations can now be seen in the progress of formation on the habitable surface of the earth — nothing, at least, within the range of human observation. The first speculators, however, in Geology found no difficulty in explaining their origin, by supposing a former condition of the planet perfectly distinct from the present, when certain chemical processes were developed on a great scale, whereby crystalline precipitates were formed, some more suddenly, in huge amorphous masses, such as granite; others by successive deposition and with a foliated and stratified structure, as in the rocks termed gneiss and mica-schist. A great part of these views have since been abandoned, more especially with regard to the origin of granite; but it is interesting to trace the train of reasoning by which they were suggested. First, the stratified primitive rocks exhibited, as was before mentioned, well-defined marks of successive accumulation, analogous to those so common in ordinary subaqueous deposits. As the latter formations were found divisible into natural groups, characterized by certain peculiarities of mineral composition, so also were the primitive. In the next place, there were discovered, in many districts, certain members of the so-called primitive series, either alternating with or passing by intermediate gradations into rocks of a decidedly mechanical origin, containing traces of organic remains. From such gradual passage the aqueous origin of the stratified crystalline rocks was fairly inferred; and as we find in the different strata of subaqueous origin every gradation between a mechanical and a purely crystalline texture, between sand, for example, and saccharoid gypsum, so it was

imagined that, in a former state of the planet, the different degrees of crystallization in the older rocks might have been dependent on the varying conditions of the menstruum from which they were precipitated.

The presence, however, of certain crystalline ingredients in the composition of many of the primary rocks rendered it necessary to resort to many arbitrary hypotheses, in order to explain their precipitation from aqueous solution; and for this reason a difference in the condition of the planet, and in the pristine energy of chemical causes, was assumed. A train of speculation originally suggested by the observed effects of aqueous agents was thus pushed beyond the limits of analogy; and it was not until a different and almost opposite course of induction was pursued, beginning with an examination of volcanic products, that more sound theoretical views were established.

Granite of igneous origin. — A passage was first traced from lava into other more crystalline igneous rocks, and from these again to granite, which last was found to send forth dikes and veins into the contiguous strata, in a manner strictly analogous to that observed in volcanic rocks, and to produce at the point of contact such changes as might be expected to result from the influence of a heated mass cooling down slowly under great pressure from a state of fusion. The want of stratification in granite supplied another point of analogy in confirmation of its igneous origin; and as some masses were found to send out veins through others, it was evident that there were granites of different ages; and that instead of forming in all cases the oldest part of the earth's crust, as had at first been

supposed, some granites were of comparatively recent origin, and newer than the stratified rocks which covered them and were pierced by granite veins.

Stratified crystalline rocks.—The theory of the origin of the other crystalline rocks was soon modified by these new views respecting the nature of granite. First it was shown, by numerous examples, that ordinary volcanic dikes might produce great alterations in the sedimentary strata which they traversed, causing them to assume a more crystalline texture, and nearly obliterating all traces of organic remains, without, at the same time, destroying the surfaces of stratification. It was also found that granite dikes and veins produced analogous, though somewhat different changes; and hence it was suggested as highly probable that the effects to which small veins gave rise, to the distance of a few yards, might be superinduced on a much grander scale where vast masses of fused rock, intensely heated for ages, came in contact at great depths from the surface with sedimentary formations. The slow action of heat in such cases, it was thought, might occasion a state of semi-fusion; so that, on the cooling down of the masses, the different materials might be arranged in new forms, according to their chemical affinities, and all traces of organic remains might disappear, while the stratiform and lamellar texture remained.

According to these views, the primary strata may have assumed their crystalline structure at as many successive periods as there have been distinct eras of the formation of granite; and their difference of mineral composition may be attributed, not to an original difference of the conditions under which they were deposited at the surface, but to subsequent modifi-

cations superinduced by heat and other causes at great depths below the surface.

The strict propriety of the term primitive, as applied to granite, and to the granitiform and associated rocks, thus became questionable; and the term primary was very generally substituted, as simply expressing the fact that the crystalline rocks, *as a mass*, were older than the *secondary*, or those which are unequivocally of a mechanical origin and contain organic remains.

Transition formations.—It has been stated that the crystalline or primary series sometimes passes by intermediate gradations into strata of mechanical origin containing organic remains. The formations of intermediate character by which that passage was effected were often observed to partake, in a perplexing degree, of the characters of the crystalline series and of those containing fossils. They were termed by Werner "transition rocks;" and he imagined that as gneiss and mica-schist had been precipitated from the waters of the first universal and chaotic ocean, so this ocean still continued to throw down some crystalline matter after the waters were inhabited by a few of the first created marine animals, and when the waves and currents had already begun to transport sand and mud, and deposit them at the bottom of the sea.

The question whether the mineral peculiarities of the rocks called transition have been derived from subsequent modifications, which sedimentary strata may in the course of ages undergo, or from some original and essential difference in their composition and structure, is one which cannot be discussed here, as it is connected with inquiries into the nature of the granitic schists which must be deferred to the end of this work.

All the stratified rocks not arranged either in the primary or transition class, were at first called secondary, a division including nearly the whole of the fossiliferous strata then known; but after some progress had been made in classifying the secondary rocks, and in assigning to each its relative place in a chronological series, another division of sedimentary formations was established, called *tertiary*, as being of newer origin than the secondary, and characterized by distinct species of fossil animals and plants. These tertiary formations were found to consist very generally of detached and isolated masses, surrounded on all sides by primary and secondary rocks, and occupying a position, in reference to the latter, very like that of the waters of lakes, inland seas, and gulfs, in relation to a continent, and, like such waters, being often of great depth, though of limited area. The imbedded organic remains were chiefly those of marine animals, but with frequent intermixtures of terrestrial and fresh-water species which are rarely found among the secondary fossils. Frequently there was evidence of the deposits having been purely lacustrine, a circumstance which had not been clearly ascertained in regard to any secondary group.

I shall consider more particularly in the fourth chapter, how far this distinction of rocks into secondary and tertiary is founded in nature, and in what relation these two great divisions may be supposed to stand to each other.

But before I offer any general views of this kind, it will be necessary to explain to the student in what manner the geologist can determine the chronological relations of mineral masses composing the crust of the earth; for as different rocks have been formed in suc-

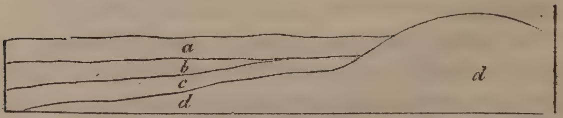
cession, one of the principal objects in geological investigations is to determine the time as well as the mode of their formation.

Proofs of relative Age by Superposition.

It is evident that, where we find a series of horizontal strata of sedimentary origin, the uppermost bed must be newer than those which it overlies; and that, when we observe one distinct set of strata reposing upon another, the inferior is the older of the two. In countries where the original position of mineral masses has been disturbed, at different periods, by convulsions of extraordinary violence, as in the Alps and other mountainous districts, there are instances where the original position of strata has been reversed. Such exceptions, however, are rare, and usually on a small scale; and an experienced observer can generally ascertain the true relations of the rocks in question, by examining some adjoining districts where the derangement has been less extensive.

Soon after the first observers had convinced themselves that strata of aqueous origin were divisible into different groups, each characterized by its peculiar fossils and mineral characters, they also ascertained that there was a determinate order of succession in these groups, which was never inverted, although the different formations were not co-extensively distributed; so

Fig. 61.



that, if there be four different formations, as *a*, *b*, *c*, *d*,

in the annexed diagram (Fig. 61.), which, in certain localities, may be seen in vertical superposition, the uppermost or newest of them, *a*, will in other places be in contact with *c*, or with the lowest of the whole series, *d*, all the intermediate formations being absent.

In regard to the age of volcanic formations, if we find a layer of tuff or ejected matter, or a stream of lava covering sedimentary strata, we may infer, with confidence, that the igneous rock is the more recent; but, on the other hand, the superposition of aqueous deposits to a volcanic mass does not always prove the superimposed beds to be of newer origin. If, indeed, we discover strata of tuff with imbedded shells, or, as in the Vicentine and other places, rolled blocks of lava, with adhering shells and corals, we may then be sure that these masses of volcanic origin covered the bottom of the sea before the superincumbent strata were thrown down. But, as lava rises from below, and does not always reach the surface, it may sometimes penetrate a certain number of strata, and then cool down, so as to constitute a solid mass of newer origin, although inferior in position. It is, for the most part, by the passage of veins proceeding from such igneous rocks through contiguous sedimentary strata, or by such hardening and other alteration of the overlying bed as might be expected to result from contact with a heated mass, that we are enabled to decide whether the volcanic matter was previously consolidated, or subsequently introduced.

Proofs by included Fragments of older Rocks.

A geologist is sometimes at a loss, after investigating a district composed of two distinct formations, to determine the relative ages of each, from want of

sections exhibiting their superposition. In such cases, another kind of evidence, of a character no less conclusive, can sometimes be obtained. One group of strata has frequently been derived from the degradation of another in the immediate neighbourhood, and may be observed to include within it fragments of such older rocks. Thus, for example, we may find chalk with flints; and, in another part of the same country, a distinct series, consisting of alternations of clay, sand, and pebbles. If some of these pebbles consist of flints, with fossil shells of the same species as those in the chalk, we may confidently infer that the chalk is the oldest of the two formations.

I have already remarked, that some granite must have existed before the most ancient of our secondary rocks, because some of the latter contain rounded pebbles of granite. But for the existence of such evidence, we might not have felt assured that all the granite which we see was not protruded from below in a state of fusion, subsequently to the origin of the secondary strata.

Proofs of contemporaneous Origin derived from Mineral Characters.

When we have established the relative age of two formations in a given place, from direct superposition, or by other evidence, a far more difficult task remains, —to trace the continuity of the same formation, or, in other cases, to find means of referring detached groups of rocks to a contemporaneous origin. Such identifications of age are chiefly derivable from two sources, —mineral character and organic contents; but the utmost skill and caution are required in the application of these tests, for scarcely any general rules can be

laid down respecting either that do not admit of important exceptions.

If at certain periods of the past, rocks of peculiar mineral composition had been precipitated simultaneously upon the floor of a "universal ocean," so as to invest the whole earth in a succession of concentric coats, the determination of relative dates in geology might have been a matter of the greatest simplicity. To explain, indeed, the phenomenon would have been difficult, or, rather, impossible, as such appearances would have implied a former state of the globe, without any analogy to that now prevailing. Suppose, for example, there were three masses extending over every continent, — the upper of chalk and chloritic sand; the next below, of blue argillaceous limestone; and the third and lowest, of red marl and sandstone: we must imagine that all the rivers and currents of the world had been charged, at the first period, with red mud and sand; at the second, with blue calcareo-argillaceous mud; and at a subsequent epoch, with chalky sediment and chloritic sand.

But, if the ocean were universal, there could have been no land to waste away by the action of the sea and rivers, and, therefore, no known source whence the homogeneous sedimentary matter could have been derived. Few, perhaps, of the earlier geologists went so far as to believe implicitly in such universality of formations, but they inclined to an opinion that they were continuous over areas almost indefinite; and since such a disposition of mineral masses would, if true, have been the least complex, and most convenient for the purposes of classification, it is probable that a belief in its reality was often promoted by the hope that it might prove true. As to the objection, that

such an arrangement of mineral masses could never result from any combination of causes now in action, it never weighed with the earlier cultivators of the science, since they indulged no expectation of being ever able to account for geological phenomena by reference to the known economy of nature. On the contrary, they set out, as we have already seen, with the assumption that the past and present conditions of the planet were too dissimilar to admit of exact comparison.

But, if we inquire into the true composition of any stratum, or set of strata, and endeavour to pursue these continuously through a country, we often find that the character of the mass changes gradually, and becomes at length so different that we should never have suspected its identity, if we had not been enabled to trace its passage from one form to another.

We soon discover that rocks dissimilar in mineral composition have originated simultaneously: we find, moreover, evidence in certain districts, of the recurrence of rocks of precisely the same mineral character at very different periods; as for example, two formations of red sandstone, with a great series of other strata intervening between them. Such repetitions might have been anticipated, since these red sandstones are produced by the decomposition of granite, gneiss, and mica-schist; and districts composed exclusively of these must again and again be exposed to decomposition, and to the erosive action of running water.

But, notwithstanding the variations before alluded to in the composition of one continuous set of strata, many rocks retain the same homogeneous structure and composition throughout considerable areas, and frequently, after a change of mineral character, pre-

serve their new peculiarities throughout other tracts of great extent. Thus, for example, we may trace a limestone for a hundred miles, and then observe that it becomes more arenaceous, until it finally passes into sand or sandstone. We may then follow the last-mentioned formation throughout another district as extensive as that occupied by the limestone first examined.

Proofs of contemporaneous Origin derived from Organic Remains.

I devoted several chapters in the last book to show that the habitable surface of the sea and land may be divided into a considerable number of distinct provinces, each peopled by a peculiar assemblage of animals and plants, and I endeavoured to point out the origin of these separate divisions. It was shown that climate is only one of many causes on which they depend; and that difference of longitude, as well as latitude, is generally accompanied by a dissimilarity of indigenous species of organic beings.

As different seas, therefore, and lakes are inhabited, at the same period, by different species of aquatic animals and plants, and as the lands adjoining these may be peopled by distinct terrestrial species, it follows that distinct organic remains are imbedded in contemporaneous deposits. If it were otherwise — if the same species abounded in every climate, or even in every part of the globe where a corresponding temperature and other conditions favourable to their existence were found, the identification of mineral masses of the same age, by means of their included organic contents, would be a matter of much greater facility. But, fortunately, the extent of the same zoological

provinces, especially those of marine animals, is very great; so that we are entitled to expect, from analogy, that the identity of fossil species, throughout large areas, will often enable us to connect together a great variety of detached formations.

Thus, for example, it will be seen, by reference to the second book, that deposits now forming in different parts of the Mediterranean, as in the deltas of the Rhone and the Nile, are distinct in mineral composition; for calcareous rocks are precipitated from the waters of the Rhone, while pebbles are carried into its delta, and there cemented, by carbonate of lime, into a conglomerate; whereas strata exclusively of soft mud and fine sand are formed in the Nilotic delta. The Po, again, carries down fine sand and mud into the Adriatic; but since this sediment is derived from the degradation of a different assemblage of mountains from those drained by the Rhone or the Nile, we may safely assume that there will never be an exact identity in their respective deposits.*

If we pass to another quarter of the Mediterranean, as, for example, to the sea on the coast of Campania, or near the base of Etna in Sicily, or to the Grecian archipelago, we find in all these localities that distinct combinations of rocks are in progress. Occasional showers of volcanic ashes are falling into the sea, and streams of lava are overflowing its bottom; and in the intervals between volcanic eruptions, beds of sand and clay are frequently derived from the waste of cliffs, or the turbid waters of rivers. Limestones, moreover, such as the Italian travertins, are here and there precipitated from the waters of mineral springs, while

* Vol. I. pp. 341. 346. 349.

shells and corals accumulate in various places. Yet the entire Mediterranean, where the above-mentioned formations are simultaneously in progress, may be considered as one zoological province; for, although certain species of testacea and zoophytes may be very local, and each region may probably have some species peculiar to it, still a considerable number are common to the whole sea. If, therefore, at some future period, the bed of this inland sea should be converted into land, the geologist might be enabled, by reference to organic remains, to prove the contemporaneous origin of various mineral masses throughout a space equal in area to a great portion of Europe. The Black Sea, moreover, is inhabited by so many species identical with those of the Mediterranean, that the deltas of the Danube and the Don might, by the same evidence, be shown to have originated simultaneously.

Such identity of fossils, I may remark, not only enables us to refer to the same era distinct rocks widely separated from each other in the horizontal plane, but also others which may be considerably distant in the vertical series. Thus, for example, we may find alternating beds of clay, sand, and lava, two thousand feet in thickness, the whole of which may be proved to belong to the same epoch, by the specific identity of the fossil shells dispersed throughout the whole series.

The reader, however, will perceive, by referring to what was before said of zoological provinces*, that they are sometimes separated from each other by very narrow barriers, and for this reason contiguous rocks may be formed at the same time, differing widely both

* See p. 100.

in mineral contents and organic remains. Thus, for example, the testacea, zoophytes, and fish of the Red Sea are, as a group, very distinct from those inhabiting the adjoining parts of the Mediterranean, although the two seas are separated only by the narrow isthmus of Suez. Calcareous formations have accumulated, on a great scale, in the Red Sea, in modern times, and fossil shells of existing species are well preserved therein *; and we know that, at the mouth of the Nile, large deposits of mud are amassed, including the remains of Mediterranean species. Hence it follows that if, at some future period, the bed of the Red Sea should be laid dry, the geologist might experience great difficulties in endeavouring to ascertain the relative age of these formations, which, although dissimilar both in organic and mineral characters, were of synchronous origin.

But we must not forget that the north-western shores of the Arabian Gulf, the plains of Egypt, and the isthmus of Suez, are all parts of one province of *terrestrial* species. Small streams, therefore, occasional land-floods, and those winds which drift clouds of sand along the deserts, might carry down into the Red Sea the same shells of fluviatile and land testacea which the Nile is sweeping into its delta, together with some remains of terrestrial plants, whereby the groups of strata, before alluded to, might, notwithstanding the discrepancy of their mineral composition, and *marine* organic fossils, be shown to have belonged to the same epoch.

In like manner, the rivers which descend into the Caribbean Sea and Gulf of Mexico on one side, and

* See chap. x.

into the Pacific on the other, carry down the same fluviatile and terrestrial spoils into seas which are inhabited by different groups of marine species.

But it will much more frequently happen, that the co-existence of *terrestrial* species of distinct zoological and botanical provinces will be proved by the specific identity of the *marine* organic remains which inhabited the intervening space. Thus, for example, the distinct terrestrial species of the south of Europe, north of Africa, and north-west of Asia, might all be shown to have been contemporaneous, if we suppose the rivers flowing from these three countries to carry the remains of different species of the animal and vegetable kingdoms into the Mediterranean.

In like manner, the sea intervening between the northern shores of Australia and the islands of the Indian Ocean contains a great proportion of the same species of corallines and testacea; yet the *land animals and plants* of the two regions are very dissimilar, even the islands nearest to Australia, as Java, New Guinea, and others, being inhabited by a distinct assemblage of terrestrial species. It is well known that there are calcareous rocks, volcanic tuff, and other strata in progress, in different parts of these intermediate seas, wherein marine organic remains might be preserved and associated with the terrestrial fossils above alluded to.

As it frequently happens that the barriers between different provinces of animals and plants are not very strongly marked, especially where they are determined by differences of temperature, there will usually be a passage from one set of species to another, as in a sea extending from the temperate to the tropical zone. In such cases, we may be enabled to prove, by the fossils

of intermediate deposits, the connexion between the distinct provinces, since these intervening spaces will be inhabited by many species, common both to the temperate and equatorial seas.

On the other hand, we may be sometimes able, by aid of a peculiar homogeneous deposit, to prove the former co-existence of distinct animals and plants in distant regions. Suppose, for example, that in the course of ages the sediment of a river, like that of the Red River in Louisiana, is dispersed over an area several hundred leagues in length, so as to pass from the tropics into the temperate zone, the fossil remains imbedded in red mud might indicate the different forms which inhabited, at the same period, those remote regions of the earth.

It appears, then, that mineral and organic characters, although often inconstant, may, nevertheless, enable us to establish the contemporaneous origin of formations in distant countries. The same species of organic beings probably extend over wider areas than deposits of homogeneous composition; and if so, they will be of more importance in geological classification even than mineral peculiarities; but it fortunately may happen that where the one criterion fails, we may often avail ourselves of the other. Thus, for example, sedimentary strata are as likely to preserve the same colour and composition in a part of the ocean reaching from the borders of the tropics to the temperate zone, as in any other quarter of the globe; but in such spaces the variation of species is always most considerable.

In conclusion, it may be observed, that in endeavouring to prove the contemporaneous origin of strata in remote countries by organic remains, we must form

our conclusions from a great number of species, since a single species may be enabled to survive vicissitudes in the earth's surface whereby thousands of others are exterminated. When a change of climate takes place, some may migrate and inhabit other latitudes, and so abound there as to become characteristic in those regions of strata of a subsequent era.

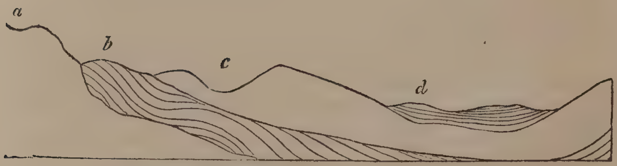
CHAPTER III.

Discovery of tertiary groups of successive periods — Paris basin — London and Hampshire basins — Tertiary strata of Bordeaux, Piedmont, Touraine, &c. (p. 359.) — Subapennine beds — English crag — More recent deposits of Sicily, &c.

HAVING in the last chapter considered some of the general rules which may enable the geologist to determine with accuracy the chronological relations of distinct sets of strata, I shall return to the history and discovery of the tertiary strata.

Paris Basin. — The first series of deposits belonging to the tertiary class, of which the characters were accurately determined, were those which occur in the neighbourhood of Paris, first described by MM. Cuvier and Brongniart.* They were ascertained to fill a de-

Fig. 62.



a. Primary rocks.
b. Older secondary formations. *c.* Chalk.
d. Tertiary formation.

pression in the chalk (as the beds *d*, in Fig. 62., rest

* Environs de Paris, 1811.

upon *c*), and to be composed of different materials, sometimes including the remains of marine and sometimes of fresh-water animals. By the aid of these fossils, several distinct alternations of marine and fresh-water formations were clearly shown to lie superimposed upon each other, and various speculations were hazarded respecting the manner in which the sea had successively abandoned and regained possession of tracts which had been occupied in the intervals by the waters of rivers or lakes. In one of the subordinate members of this Parisian series, a great number of scattered bones and skeletons of land animals were found entombed, the species being perfectly dissimilar to any known to exist, as indeed were those of almost all the animals and plants of which any portions were discovered in the associated deposits.

I must defer, to another part of this work, a more detailed account of this interesting formation, and shall merely observe, in this place, that the investigation of the fossil contents of these beds forms an era in the progress of the science. The French naturalists brought to bear upon their geological researches so much skill and proficiency in comparative anatomy and conchology, as to place in a strong light the importance of the study of organic remains, and the comparatively subordinate interest attached to the exclusive investigation of the structure and mineral ingredients of rocks.

A variety of tertiary formations were soon afterwards found in other parts of Europe, as in the south-east of England, in Italy, Austria, and different parts of France, especially in the basins of the Loire and Gironde, all strongly contrasted with the secondary rocks. As in the latter class many different divisions had been ob-

served to preserve the same mineral characters and organic remains over wide areas, it was natural that an attempt should first be made to trace the different subdivisions of the Parisian tertiary strata throughout Europe, for some of these were not inferior in thickness to several of the secondary formations which had a wide range.

But in this case the analogy, however probable, was not found to hold good; and the error, though almost unavoidable, retarded seriously the progress of geology. As often as a new tertiary group was discovered, as that of Italy, for example, an attempt was invariably made, in the first instance, to discover in what characters it agreed with some one or more subordinate members of the Parisian type. Every fancied point of correspondence was magnified into undue importance, and such trifling circumstances, as the colour of a bed of sand or clay, were dwelt upon as proofs of identity, while the general difference in the mineral character and organic contents of the group from the whole Parisian series was slurred over and thrown into the shade.

By the influence of this illusion, the succession and chronological relations of different tertiary groups were kept out of sight. The difficulty of clearly discerning these arose from the frequent isolation of the position of the tertiary formations before described, since, in proportion as the areas occupied by them are limited, it is rare to discover a place where one set of strata overlap another, in such a manner that the geologist might be enabled to determine the difference of age by direct superposition.

THE EUROPEAN TERTIARY STRATA FORMED AT SUCCESSIVE PERIODS.

I shall now very briefly enumerate some of the principal steps which eventually led to a conviction of the necessity of referring the European tertiary formations to distinct periods, and the leading data by which such a chronological series may be established.

London and Hampshire Basins. — Very soon after the investigation, before alluded to, of the Parisian strata, those of Hampshire and of the basin of the Thames were examined in our own country. Mr. Webster found these English tertiary deposits to repose, like those in France, upon the chalk, or newest rock of the secondary series. He identified a great number of the shells occurring in the British and Parisian strata, and ascertained that, in the Isle of Wight, an alternation of marine and freshwater beds occurred, very analogous to that observed in the basin of the Seine.* But no two sets of strata could well be more dissimilar in mineral composition, and they were only recognized to belong to the same era by aid of the specific identity of their organic remains. The discordance, in other respects, was as complete as could well be imagined, for the principal marine formation in the one country consisted of blue clay, in the other of white limestone; and a variety of curious rocks in the neighbourhood of Paris had no representatives whatever in the south of England.

Subapennine beds.— The next important discovery of tertiary strata was in Italy, where Brocchi traced

* Webster in Englefield's Isle of Wight and Geol. Trans., vol. ii. p. 161.

them along the flanks of the Apennines, from one extremity of the peninsula to the other, usually forming a lower range of hills, called by him the Subapennines.* These formations, it is true, had been pointed out by the older Italian writers; and some correct ideas, as we have seen, had been entertained respecting their recent origin, as compared to the inclined secondary rocks on which they rested.† But accurate data were now for the first time collected, for instituting a comparison between them and other members of the great European series of tertiary formations.

Brocchi came to the conclusion that nearly one-half of several hundred species of fossil shells procured by him from these Subapennine beds were identical with those now living in existing seas, an observation which did not hold true in respect to the organic remains of the Paris basin. It might have been supposed that this important point of discrepancy would at once have engendered great doubt as to the identity, in age, of any part of the Subapennine beds with any one member of the Parisian series; but, for the reasons above alluded to, this objection was not thought of much weight, and it was supposed that a group of strata, called "the upper marine formation," in the basin of the Seine, might be represented by all the Subapennine clays and yellow sand.

English Crag. — Several years before, an English naturalist, Mr. Parkinson, had observed that certain shelly strata, in Suffolk, which lay over the blue clay of London, contained distinct fossil species of testacea, and that a considerable portion of these might be identified with species now inhabiting the neighbouring

* Conch. Foss. Subap., 1814.

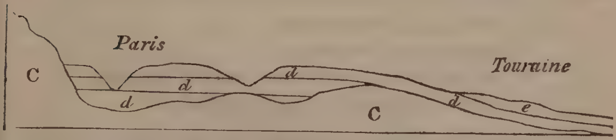
† See Vol. I. p. 73., for opinions of Odoardi in 1761.

sea.* These overlying beds, which were provincially termed "crag," were of small thickness, and were not regarded as of much geological importance. But, when duly considered, they presented a fact worthy of great attention, viz., the superposition of a tertiary group, enclosing, like the Subapennine beds, a great intermixture of recent species of shells, upon tertiary beds wherein a very few remains of recent or living species were entombed.

Mr. Conybeare, in his excellent classification of the English strata †, placed the crag as the uppermost of the British series; and several geologists began soon to entertain an opinion that this newest of our tertiary formations might correspond in age to the Italian strata described by Brocchi.

Tertiary strata of Touraine. — The next step towards establishing a succession of tertiary periods was the evidence adduced to prove that certain formations more recent than the uppermost members of the Parisian series, were also older than the Subapennine beds, so that they constituted deposits of an age intermediate between the two types above alluded to. M. Desnoyers, for example, ascertained that a group

Fig. 63.



C. Chalk and other secondary formations.
d. Tertiary formation of Paris basin.
e. Superimposed marine tertiary beds of the Loire.

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* Geol. Trans., vol. i. p. 324., 1811.

† Outlines of the Geology of England and Wales, 1822.

of marine strata, in Touraine, in the basin of the Loire (*e*, Fig. 63.), rest upon the uppermost subdivision of the Parisian group *d*, which consists of a lacustrine formation, extending continuously throughout a platform which intervenes between the basin of the Seine and that of the Loire. These overlying marine strata, M. Desnoyers assimilated to the English crag, to which they bear some analogy, although their organic remains differ considerably, as will be afterwards shown.

A large tertiary deposit had already been observed in the south-west of France, around Bordeaux and Dax, and a description of its fossils had been published by M. de Basterot.* Many of the species were peculiar, and differed from those of the strata now called Subapennine; yet these same peculiar and characteristic fossils reappeared in Piedmont, in a series of strata inferior in position to the Subapennines (as *e* underlies *f*, Fig. 64.)

Fig. 64.

C. Chalk and older formations.
d. London clay (older tertiary).
e. Tertiary strata of same age as beds of the Loire.
f. Crag and Subapennine tertiary deposits.

This inferior group, *e*, composed principally of green sand, occurs in the hills of Mont Ferrat, and beds of the same age are seen in the valley of the Bormida. They also form the hill of the Superga, near Turin,

* Mém. de la Soc. d'Hist. Nat. de Paris, tome ii., 1825.

where Signor Bonelli first formed a large collection of their fossils, and identified them with those discovered near Bordeaux and in the basin of the Gironde.*

But we are indebted to M. Deshayes for having proved, by a careful comparison of the entire assemblage of shells found in the above-mentioned localities, in Touraine, in the south-west of France, and in Piedmont, that the whole of these three groups possess the same zoological characters, and belong to the same epoch, as also do the shells described by M. Constant Prevost, as occurring in the basin of Vienna.†

Now the reader will perceive, by reference to the observations above made, and to the accompanying diagrams, that one of the formations of this intervening period, *e*, has been found superimposed upon the highest member of the Parisian series, *d;* while another of the same set has been observed to underlie the Subapennine beds, *f.* Thus the chronological series, *d*, *e*, *f*, is made out, in which the deposits, originally called tertiary, those of the Paris and London basins, for example, occupy the lowest position, and the beds called "the crag," and "the Subapennines," the highest.

Tertiary strata newer than the Subapennine.— The fossil remains which characterize each of the three successive periods above alluded to, approximate more nearly to the assemblage of *species* now existing, in proportion as their origin is less remote from our own era, or, in other words, the recent species are always

* For farther notice of the labours of Signor Bonelli and others on this subject, see below, ch. v.

† Sur la Constitution, &c. du Bassin de Vienne, Journ. de Phys., Nov. 1820.

more numerous, and the extinct more rare, in proportion to the low antiquity of the formation. But the discordance between the state of the organic world indicated by the fossils of the Subapennine beds and the actual state of things is still considerable, and we naturally ask, are there no monuments of an intervening period? — no evidences of a gradual passage from one condition of the animate creation to that which now prevails, and which differs so widely?

It will appear, in the sequel, that such monuments are not wanting, and that there are marine strata entering into the composition of extensive districts, and of hills of no trifling height, which contain the exuviæ of testacea and zoophytes, hardly distinguishable, as a group, from those now peopling the neighbouring seas. Thus the line of demarcation between the actual period and that immediately antecedent, is quite evanescent, and the newest members of the tertiary series will be often found to blend with the formations of the historical era.

In Europe, these modern strata have been found in the district round Naples, in the territory of Otranto and Calabria, and more particularly in the island of Sicily; and the bare enumeration of these places cannot fail to remind the reader, that they belong to regions where the volcano and the earthquake are now active, and where we might have anticipated the discovery of emphatic proofs that the conversion of sea into land had been of frequent occurrence at very modern periods.

CHAPTER IV.

DIFFERENT CIRCUMSTANCES UNDER WHICH THE SECONDARY AND TERTIARY FORMATIONS MAY HAVE ORIGINATED.

Secondary series formed when the ocean prevailed; tertiary during the conversion of sea into land, and the growth of a continent — Origin of interruption in the sequence of formations — The areas where new deposits take place are always shifting — Causes of this — Denudation augments the discordance in the age of rocks in contact (p. 371.) — Unconformability of overlying formations — In what manner the shifting of the areas of sedimentary deposition may combine with the gradual extinction and introduction of species to produce a series of deposits having distinct mineral and organic characters.

I HAVE already glanced at the origin of some of the principal points of difference in the characters of the primary and secondary rocks, and may now briefly consider the relation in which the secondary stand to the tertiary, and the causes of that succession of tertiary formations, which has been described in the last chapter.

It is evident that large parts of Europe must have been sea at one and the same time when different portions of the secondary series were formed, because we find homogeneous mineral masses, including the remains of similar marine animals, referrible to the secondary period, extending over great areas; whereas the detached and isolated position of the tertiary groups, in basins, or depressions bounded by secondary and

primary rocks, favours the hypothesis of a sea interrupted by extensive tracts of dry land.

State of the Surface when the Secondary Strata were formed.

Let us consider the changes that must be expected to accompany the gradual conversion of part of the bed of an ocean into a continent, and the different characters that might be imparted to subaqueous deposits formed during the period when the sea prevailed, as contrasted with those that might belong to the subsequent epoch when the land should predominate. First, we may suppose a vast submarine region, such as the bed of the western Atlantic, to receive for ages the turbid waters of several great rivers, like the Amazon, Orinoco, or Mississippi, each draining a considerable continent. The sediment thus introduced might be characterized by a peculiar colour and composition, and the same homogeneous mixture might be spread out over an immense area by the action of a powerful current, like the Gulf-stream. First, one submarine basin, and then another, might be filled, or rendered shallow, by the influx of transported matter, the same species of animals and plants still continuing to inhabit the sea; so that the organic, as well as the mineral characters, might be constant throughout the whole series of deposits.

In another part of the same ocean, let us suppose masses of coralline and shelly limestone to grow, like those of the Pacific, simultaneously over a space several thousand miles in length; and thirty or forty degrees of latitude in breadth, while volcanic eruptions give rise, at different intervals, to igneous rocks, having a common character in different parts of the vast area.

It is evident that, during such a state of a certain quarter of the globe, limestone and other rocks might be formed, and retain a common character over spaces equal to a large portion of Europe.

State of the Surface when the Tertiary Groups were formed.

But, when by the instrumentality of causes now in action, in the manner already described, the area under consideration began to be converted into land, a very different condition of things must succeed. A series of subterranean movements might first give rise to small rocks and islets, and then, by subsequent elevations, to larger islands, by the junction of those first raised. These lands would consist partly of the mineral masses before described, whether coralline, sedimentary, or volcanic, and partly of the subjacent rocks, whatever they may have been, which constituted the original bed of the ocean. Now the degradation of these lands would commence immediately upon their emergence, the waves of the sea undermining the cliffs, and torrents flowing from the surface, so that new strata would begin to form in different places, at the bottom of the still remaining seas; and, in proportion as the lands increased, these deposits would augment.

At length, by the continued rising and sinking of different parts of the bed of the ocean, a number of distinct basins would be formed, wherein different kinds of sediment, each distinguished by some local character, might accumulate. Some of the groups of islands that had first risen would, in the course of ages, become the central mountain ranges of continents, and different lofty chains might thus be characterized by similar

rocks of contemporaneous origin, the component strata having originated under analogous circumstances in the ocean before described.

Finally, when large tracts of land existed, there would be a variety of disconnected gulfs, inland seas, and lakes, each receiving the drainage of distinct hydrographical basins, and becoming the receptacles of stratified matter, distinguished by marked peculiarities of mineral composition. The organic remains would also be more varied, for in one locality freshwater species would be imbedded, as in the deposits now forming in the lakes of Switzerland and the north of Italy; in another, marine species, as in the Aral and Caspian; in a third region, gulfs of brackish water would be converted into land, like those of Bothnia and Finland in the Baltic; in a fourth, there might be great fluviatile and marine formations along the borders of a chain of inland seas, like the deltas now growing at the mouths of the Don, Danube, Nile, Po, and Rhone, along the shores of the Sea of Azof, the Euxine, and Mediterranean. These deposits would each partake more or less of the peculiar mineral character of adjoining lands, the degradation of which would supply sediment to the different rivers.

Now, if such be, in a great measure, the distinction between the circumstances under which the secondary and tertiary series originated, it is quite natural that particular tertiary groups should occupy areas of comparatively small extent—that they should frequently consist of littoral and lacustrine deposits—and that they should often contain those admixtures of terrestrial, freshwater, and marine remains, which are so rare in secondary rocks. It might also be expected that the

tertiary volcanic formations should be much less exclusively submarine; and this we accordingly find to be the case.

Causes of the Superposition of successive Formations having distinct Mineral and Organic Characters.

But we have still to account for those remarkable breaks in the series of superimposed formations, which are common both to the secondary and tertiary rocks, but are more particularly frequent in the latter. The elucidation of this curious point is the more important, because some geologists appeal to phenomena of this kind in support of their doctrine of sudden revolutions of the globe, and great catastrophes out of the ordinary course of nature.

It is only by carefully considering the combined action of all the causes of change now in operation, whether in the animate or inanimate world, that we can hope to explain such complicated appearances as are exhibited in the general arrangement of mineral masses. In attempting, therefore, to trace the origin of these violations of continuity, we must recur to many of the topics treated of in the two last books, such as the effects of the various agents of decay and reproduction, the imbedding of organic remains, and the extinction of species.

Shifting of the areas of sedimentary deposition.—By reverting to our survey of the destroying and renovating agents, it will be seen that the surface of the terraqueous globe may be divided into two parts, one of which is undergoing repair, while the other, constituting, at any one period, by far the larger portion of the whole, is either suffering degradation, or remaining stationary without loss or increment. The reader will

assent at once to this proposition, when he reflects that the dry land is, for the most part, wasting by the action of rain, rivers, and torrents; and that part of the bed of the sea is exposed to the excavating action of currents, while the greater part, remote from continents and islands, receives no new deposits. For as a turbid river throws down all its sediment into the first lake which it traverses, so currents flowing from the land or from shoals purge themselves from foreign ingredients in the first deep basin which they enter, and beyond this the blue waters of the ocean may for ages remain clear to the greatest depths. If there are any relics of organic beings at the bottom, they may decompose like the leaves of the forest in autumn, leaving no vestige behind, but merely supplying nourishment, by their decomposition, to succeeding races of marine animals and plants.

The other part of the terraqueous surface is the receptacle of new deposits; and in this portion alone, as I pointed out in the last book, the remains of animals and plants become fossilized. Now the position of this area, where new formations are in progress, and where alone any memorials of the state of organic life are preserved, is always varying, and must for ever continue to vary: and, for the same reason, that portion of the terraqueous globe which is undergoing waste also shifts its position, and these fluctuations depend partly on the action of aqueous, and partly of igneous causes.

In illustration of these positions, I may observe, that the sediment of the Rhone, which is thrown into the Lake of Geneva, is now conveyed to a spot a mile and a half distant from that where it accumulated in the tenth century, and six miles from the point where the

delta began originally to form. We may look forward to the period when the lake will be filled up, and then a sudden change will take place in the distribution of the transported matter; for the mud and sand brought down from the Alps will thenceforth, instead of being deposited near Geneva, be carried nearly two hundred miles southwards, where the Rhone enters the Mediterranean.

The additional matter thus borne down to the lower delta of the Rhone would not only accelerate its increase, but might affect the mineral character of the strata there deposited, and thus give rise to an upper group, or subdivision of beds, having a distinct character. But the filling up of a lake, and the consequent transfer of the sediment to a new place, may sometimes give rise to a still more abrupt transition from one group to another; as, for example, in a gulf like that of the St. Lawrence, at the head of which no deposits are now accumulated, the river being purged of all its impurities in its previous course through the Canadian lakes. Should the lowermost of these lakes be at any time filled up with sediment, or laid dry by earthquakes, the waters of the river would thenceforth become turbid, and strata would begin to be deposited in the gulf, where a new formation would immediately overlie the ancient rocks now constituting the bottom. In this case there would be an abrupt passage from the inferior and more ancient, to the newer superimposed formation.

The same sudden coming on of new sedimentary deposits, or the suspension of those which were in progress, must frequently occur in different submarine basins where the prevailing currents are always liable, in the course of ages, to change their direction. Sup-

pose, for instance, a sea to be filling up in the same manner as the Adriatic, by the influx of the Po, Adige, and other rivers. The deltas, after advancing and converging, may at last come within the action of a transverse current, which may arrest the further deposition of matter and sweep it away to a distant point. Such a current now appears to prey upon the delta of the Nile, and to carry eastward the annual accessions of sediment that once added rapidly to the plains of Egypt.

On the other hand, if a current charged with sediment vary its course,—a circumstance which, as I have shown, must happen to all of them in the lapse of ages,—the accumulation of transported matter will at once cease in one region, and commence in another.

Although the causes which occasion the transference of the places of sedimentary deposition are continually in action in every region, yet they are particularly influential where subterranean movements alter, from time to time, the levels of land; and their effect must be very great during the successive elevations and depressions which must be supposed to accompany the rise of a great continent from the deep. A trifling change of level may sometimes throw a current into a new direction, or alter the course of a considerable river. Some tracts will be alternately submerged and laid dry by subterranean movements: in one place a shoal will be formed, whereby the waters will drift matter over spaces where they once threw down their burden, and new cavities will elsewhere be produced, both marine and lacustrine, which will intercept the waters bearing sediment, and thereby stop the supply once carried to some distant basin.

I have before stated, that a few earthquakes of mo-

derate power might cause a subsidence which would connect the Sea of Azof with a large part of Asia now below the level of the ocean.* This vast depression, recently shown by Humboldt to extend over an area of eighteen thousand square leagues, surrounds Lake Aral and the Caspian; on the shores of which seas it sinks in some parts to the depth of about 350 feet below the level of the ocean. The whole area might thus suddenly become the receptacle of new beds of sand and shells, probably differing in mineral character from the masses previously existing in that country; for an exact correspondence could arise only from a precise identity in the whole combination of circumstances which should give rise to formations produced at different periods in the same place.

Without entering into more detailed explanations, the reader will perceive that, according to the laws now governing the aqueous and igneous causes, distinct deposits must, at different periods, be thrown down on various parts of the earth's surface, and that, in the course of ages, the same area may become, again and again, the receptacle of such dissimilar sets of strata. During intervening periods, the space may either remain unaltered, or suffer what is termed *denudation;* in which case a superior set of strata is removed by the power of running water, and subjacent beds are laid bare, as happens wherever a sea encroaches upon a line of coast. By such means, it is obvious that the discordance in age of rocks in contact must often be greatly increased.

The frequent unconformability in the stratification of the inferior and overlying formation is another phe-

* See p. 148.

nomenon in their arrangement, which may be considered as a natural consequence of those movements that accompany the gradual conversion of part of an ocean into land: for by such convulsions the older set of strata may become rent, shattered, inclined, and contorted to any amount. If the movement cease entirely, before a new deposit is formed in the same tract, the superior strata may repose horizontally upon the dislocated series. But even if the subterranean convulsions continue with increasing violence, the more recent formations must remain comparatively undisturbed, because they cannot share in the derangement previously produced in the older beds; while the latter, on the contrary, cannot fail to participate in all the movements subsequently communicated to the newer.

Change of species every where in progress.—If, then, it be conceded that the combined action of the volcanic and the aqueous forces would give rise to a succession of distinct formations, and that these would be sometimes unconformable, let us next inquire in what manner these groups might become characterized by different assemblages of fossil remains.

I endeavoured to show, in the last book, that the hypothesis of the gradual extinction of certain animals and plants, and the successive introduction of new species, was quite consistent with all that is known of the existing economy of the animate world; and if it is found to be the only hypothesis which is reconcilable with geological phenomena, we shall have strong grounds for conceiving that such is, and has been, the order of nature.

Fossilization of plants and animals partial.— We have seen that the causes which limit the duration of

species are not confined, at any one time, to a particular part of the globe; and, for the same reason, if we suppose that their place is supplied, from time to time, by new species, we may suppose their introduction to be no less generally in progress. It would follow, therefore, from all the foregoing premises, that the change of species would be in simultaneous operation every where throughout the habitable surface of sea and land; whereas the fossilization of plants and animals must always be confined to those areas where new strata are produced. These areas, as has been proved, are always shifting their position; so that the fossilizing process, by means of which the commemoration of the particular state of the organic world, at any given time, is effected, may be said to move about, visiting and revisiting different tracts in succession.

In order more distinctly to elucidate my idea of the working of this machinery, I shall compare it to a somewhat analogous case that might easily be imagined to occur in the history of human affairs. Let the mortality of the population of a large country represent the successive extinction of species, and the births of new individuals the introduction of new species. While these fluctuations are gradually taking place every where, suppose commissioners to be appointed to visit each province of the country in succession, taking an exact account of the number, names, and individual peculiarities of all the inhabitants, and leaving in each district a register containing a record of this information. If, after the completion of one census, another is immediately made on the same plan, and then another, there will, at last, be a series of statistical documents in each province. When these are arranged in chronological order, the contents of those

which stand next to each other will differ according to the length of the intervals of time between the taking of each census. If, for example, there are sixty provinces, and all the registers are made in a single year and renewed annually, the number of births and deaths will be so small, in proportion to the whole of the inhabitants, during the interval between the compiling of two consecutive documents, that the individuals described in such documents will be nearly identical; whereas, if the survey of each of the sixty provinces occupies all the commissioners for a whole year, there will be an almost entire discordance between the persons enumerated in two consecutive registers in the same province. There are undoubtedly other causes besides the mere quantity of time, which may augment or diminish the amount of discrepancy. Thus, at some periods a pestilential disease may have lessened the average duration of human life, or a variety of circumstances may have caused the births to be unusually numerous, and the population to multiply; or, a province may be suddenly colonized by persons migrating from surrounding districts.

I must also remind the reader, that I do not propose the case as an exact parallel to those geological phenomena which I desire to illustrate; for the commissioners are supposed to visit the different provinces in rotation; whereas the commemorating processes by which organic remains become fossilized, although they are always shifting from one area to another, are yet very irregular in their movements. They may abandon and revisit many spaces again and again, before they once approach another district; and, besides this source of irregularity, it may often happen that, while the depositing process is suspended, denudation may

take place, which may be compared to the occasional destruction by fire or other causes of some of the statistical documents before mentioned. It is evident that, where such accidents occur, the want of continuity in the series may become indefinitely great, and that the monuments which follow next in succession will by no means be equidistant from each other in point of time.

If this train of reasoning be admitted, the distinctness of the fossil remains, in formations immediately in contact, would be a necessary consequence of the existing laws of sedimentary deposition, and of a constant mortality and renovation of species.

I have already stated, that we should naturally look for a change in the mineral character in strata thrown down at distant intervals in the same place; and, in like manner, we must also expect, for the reason last set forth, to meet occasionally with sudden transitions from one set of organic remains to another. But the causes which have given rise to such differences in mineral characters have no necessary connexion with those which have produced a change in the species of imbedded plants and animals.

When the lowest of two sets of strata are much dislocated throughout a wide area, the upper being undisturbed, there is usually a considerable discordance in the organic remains of the two groups; but the coincidence, in this instance, of the point where the fossils and the stratification change their character, must not be ascribed to the agency of the disturbing forces, as if they had exterminated the living inhabitants of the surface. The *lapse of time* assumed to be requisite for the development of so great a series of subterranean movements has, in such cases, allowed the

species also throughout the globe to vary, and hence the two phenomena are usually concomitant.

Although these inferences appear to me very obvious, I am aware that they are directly opposed to many popular theories respecting catastrophes; I shall, therefore, endeavour to illustrate these views still more clearly by another analogous case. Suppose we had discovered two buried cities at the foot of Vesuvius, immediately superimposed upon each other, with a great mass of tuff and lava intervening, just as Portici and Resina, if now covered with ashes, would overlie Herculaneum. An antiquary might possibly be entitled to infer, from the inscriptions on public edifices, that the inhabitants of the inferior and older town were Greeks, and those of the modern Italians. But he would reason very hastily, if he also concluded, from these data, that there had been a sudden change from the Greek to the Italian language in Campania. Suppose he afterwards found *three* buried cities, one above the other, the intermediate one being Roman, while, as in the former example, the lowest was Greek, and the uppermost Italian; he would then perceive the fallacy of his former opinion, and would begin to suspect that the catastrophes, by which the cities were inhumed, might have no relation whatever to the fluctuations in the language of the inhabitants; and that, as the Roman tongue had evidently intervened between the Greek and Italian, so many other dialects may have been spoken in succession, and the passage from the Greek to the Italian may have been very gradual; some terms growing obsolete, while others were introduced from time to time.

If this antiquary could have shown that the volcanic paroxysms of Vesuvius were so governed as that cities

should be buried one above the other, just as often as any variation occurred in the language of the inhabitants, then, indeed, the abrupt passage from a Greek to a Roman, and from a Roman to an Italian city, would afford proof of fluctuations no less sudden in the language of the people.

So, in Geology, if we could assume that it is part of the plan of nature to preserve, in every region of the globe, an unbroken series of monuments to commemorate the vicissitudes of the organic creation, we might infer the sudden extirpation of species, and the simultaneous introduction of others, as often as two formations in contact are found to include dissimilar organic fossils. But we must shut our eyes to the whole economy of the existing causes, aqueous, igneous, and organic, if we fail to perceive *that such is not the plan of Nature.*

CHAPTER V.

CLASSIFICATION OF TERTIARY FORMATIONS IN CHRONOLOGICAL ORDER.

Comparative value of different classes of organic remains — Fossil remains of testacea the most important — Necessity of accurately determining species — Four subdivisions of the tertiary epoch proposed — Recent formations (p. 385.) — Newer Pliocene period — Older Pliocene period — Miocene period — — Eocene period — The distinct zoological characters of these periods may not imply sudden changes in the animate creation — Numerical proportion of recent species of shells in different tertiary periods (p. 395.) — The recent strata form a common point of departure in distant regions — Mammiferous remains — Synoptical table of recent and tertiary formations.

In the second chapter I explained the principles on which the relative ages of different formations may be ascertained, and the distinctive character was found to be chiefly derivable from superposition, mineral structure, and organic remains. It is by combining the evidence deducible from all these sources, that we are enabled to determine the chronological succession of distinct formations.

It will be seen, that in proportion as investigations have been extended over a larger area, it has become necessary to intercalate new groups of an age intermediate between those first examined; and we have every reason to expect that, as the science advances, new links in the chain will be supplied, and that the

passage from one period to another will become less abrupt. We may even hope, without travelling to distant regions, — without even transgressing the limits of western Europe, to render the series far more complete. The fossil shells, for example, of many of the Subalpine formations, on the northern limits of the plains of the Po, have not yet been carefully collected and compared with those of other countries, and we are almost entirely ignorant of many deposits known to exist in Spain and Portugal.

The views developed in the last chapter, respecting breaks in the sequence of geological monuments, will explain our reasons for anticipating the discovery of intermediate gradations as often as new regions of great extent are explored.

Comparative Value of different Classes of Organic Remains.

In the mean time, we must endeavour to make the most systematic arrangement in our power of those formations which are already known; and in attempting to classify these in chronological order, we must chiefly depend on the evidence afforded by their fossil organic contents. In the execution of this task we have first to consider what class of remains are most useful; for although every kind of fossil animal and plant is interesting, and cannot fail to throw light on the former history of the globe at a certain period, yet those classes of remains which are of rare and casual occurrence are absolutely of no use for the purposes of general classification. If we have plants alone in one assemblage of strata, and the bones of mammalia in another, we can draw no conclusion respecting the number of species of organic beings

common to two epochs; or if we have plants and vertebrated animals in one series, and only shells in another, we can form no opinion respecting the remoteness or proximity of the two eras. We might, perhaps, draw some conclusions as to relative antiquity, if we could compare each of the two formations to a third; as, for example, if the species of shells should be almost all identical with those now living, while the plants and vertebrated animals were all extinct; for we might then infer that the shelly deposit was the most recent of the two. But in this case the information would flow from a direct comparison of the species of corresponding orders of the animal and vegetable kingdoms, —of plants with plants, and shells with shells; the only mode of making a systematic arrangement by reference to organic remains.

Although the bones of mammalia in the tertiary strata, and those of reptiles in the secondary, afford us instruction of the most interesting kind, yet the species are too few, and confined to too small a number of localities, to be of much value in characterizing the subdivisions of geological formations. The remains of fish will soon become of much more importance, although the science of fossil ichthyology is still so new that there has been scarcely as yet time for the application of its results to geology. The researches of Mr. Agassiz have recently enabled him to determine the existence in European collections of no less than 850 species, which are distributed largely through deposits of every age. A mere tooth, or a few scales, is often sufficient for the recognition of a species, and the range of species in this class seems, in general, to be very limited in the vertical series; in other words, the same species is rarely common to two or more distinct groups of super-

imposed strata. Yet these same fish are said to have a very wide horizontal range; that is to say, are found fossil in the same formations in countries extremely distant. Should farther investigation confirm these views of Mr. Agassiz respecting the constancy of their characters and their limitation to particular formations, no class of fossils will contribute more powerfully than fossil fish to the identification of contemporaneous strata in distant parts of the earth.

We can scarcely hope to derive equal assistance from fossil botany, as it is only in a few formations, and in certain kinds of rock, that plants are numerous and well preserved. In these places, however, they throw great light on the former state of the globe at the periods to which they refer. Even in regard to zoophytes, which are so much more abundant in a fossil state than any of the classes above enumerated, we have hitherto been impeded in our endeavour to classify strata by their aid, in consequence of the smallness of the number of recent species which have been examined from those tropical seas where they occur in the greatest profusion. But these difficulties will soon be lessened, and Mr. Ehrenberg's recent investigation of the corals of the Red Sea has greatly advanced this department of science.*

Fossil remains of testacea of chief importance.—The testacea then are by far the most important class of organic beings which have left their spoils in the subaqueous deposits; and they have been truly said to be the medals which nature has chiefly selected to record the history of the former changes of the globe. There is scarcely any great series of strata that does not con-

* See Book iii. chap. xviii.

tain some marine or freshwater shells; and these fossils are often found so entire, especially in the tertiary formations, that when disengaged from the matrix, they have all the appearance of having been just procured from the sea. Their colour, indeed, is usually wanting, but the parts whereon specific characters are founded remain unimpaired; and though the animals themselves are gone, their form and habits can generally be inferred from the shell which covered them.

The utility of the testacea, in geological classification, is greatly enhanced by the circumstance that some forms are proper to the sea, others to the land, and others to fresh water. Rivers scarcely ever fail to carry down into their deltas some land shells, together with species which are at once fluviatile and lacustrine. The Rhone, for example, receives annually, from the Durance, many shells which are drifted in an entire state from the higher Alps of Dauphiny; and these species, such as *Bulimus montanus*, are carried down into the delta of the Rhone to a climate very different from that of their native habitation. The young hermit crabs may often be seen on the shores of the Mediterranean, near the mouth of the Rhone, inhabiting these univalves, brought down to them from so great a distance.* At the same time that some freshwater and land shells are carried into the sea, other individuals of the same species become fossil in inland lakes, and by this means we learn what species of freshwater and marine testacea coexisted at particular eras. We also make out the connexion between various plants and mammifers imbedded in those lacustrine deposits,

* M. Marcel de Serres pointed out this curious fact to me when I visited Montpellier, July, 1828.

and the testacea which lived at the same time in the ocean.

There are two other characters of the molluscous animals which render them extremely valuable in settling chronological questions in Geology. The first of these is a wide geographical range, and the second (probably a consequence of the former) is the superior duration of species in this class. It is evident that if the habitation of a species be very local, it cannot aid us greatly in establishing the contemporaneous origin of distant groups of strata, in the manner pointed out in the last chapter; and if a wide geographical range be useful in connecting formations far separated in space, the longevity of species is no less serviceable in establishing the relations of strata considerably distant from each other in point of time.

I shall revert in the sequel to the curious fact, that in tracing back the series of tertiary deposits from the newer to the older, many existing species of testacea accompany us after the disappearance of all fossil remains of the recent mammalia and fish. We even find the skeletons of extinct quadrupeds in deposits wherein all the land and freshwater shells are of living species.*

Necessity of accurately determining species. — The reader will already perceive that the systematic arrangement of strata, so far as it rests on organic remains, must depend essentially on the accurate determination of *species;* and the geologist must therefore have recourse to the ablest naturalists, devoted to the study of certain departments of organic nature. It is scarcely possible that they who are continually employed in laborious investigations in the field, and in

* See Vol. I. p. 142., and Book iv. chap. xi.

ascertaining the relative position and characters of mineral masses, should have leisure to acquire a profound knowledge of fossil osteology, conchology, and other branches of zoological inquiry; but it is desirable that in these sciences they should become acquainted with the principles at least on which specific characters are determined, and the habits of species inferred from their peculiar forms.

When the specimens of shells are in an imperfect state of preservation, or happen to belong to genera in which it is difficult to decide on the species, except the inhabitant itself be present, or when any other grounds of ambiguity arise, we must reject, or lay small stress upon, the evidence, lest we vitiate our general results. We cannot do better than consider the steps by which the science of botanical geography has reached its present stage of advancement, and endeavour to introduce the same severe comparison of the specific characters, in drawing our geological inferences.

SUBDIVISIONS OF THE TERTIARY EPOCH.

I shall now proceed to consider the subdivisions of tertiary strata which may be founded on the results of a comparison of their respective fossils, and to give names to the periods to which they may be severally referred. But, first, it will be necessary to explain the difference between the *tertiary* phenomena and those described in the last two books. In the present work all those geological monuments are called tertiary which are newer than the secondary formations, and which on the other hand cannot be proved to have originated since the earth was inhabited by man. Part of the changes, whether of the animate or in-

animate world, considered in the preceding books, was ascertained by historical testimony to have taken place within the human epoch; as, for example, the accumulation of the newer portion of the deltas of the Po, Rhone, and Nile. Another part, where history was silent, was proved to belong to the same epoch by the evidence of the fossil remains of man or his works. All formations, whether igneous or aqueous, which can be shown by any such proofs to be of a date posterior to the introduction of man, will be called *Recent*. Some authors have applied the term *contemporaneous* in the same sense; but as this word is so frequently in use to express the synchronous origin of distinct rocks of every age, it would be a source of great inconvenience and ambiguity if we were to confine it to a technical meaning.

The European tertiary strata may be referred to four successive periods, each characterized by containing a very different proportion of fossil shells of *recent* species. I have considered that it may be useful to distinguish these four periods by the following terms: Newer Pliocene, Older Pliocene, Miocene, and Eocene. But, before explaining their etymology, and the geological characters of the several groups which they designate, it will be proper to point out some of the steps by which I was led to adopt a fourfold division, and to acknowledge the co-operation of other geologists, who about the same time, and from independent observations, had come to conclusions very similar to my own.

Before I visited Turin in 1828, in company with Mr. Murchison, I had already conceived the idea of classing the different tertiary groups by reference to the proportional number of recent species found fossil

in each. Signor Bonelli then informed us, that the fossil shells of the hill of the Superga differed as a group from those of Parma and other localities of the Subapennine beds of northern Italy; and, on the other hand, that the characteristic shells of the Superga agreed with the species found at Bordeaux and other parts of the south of France. We were the more struck with this remark, as we had already inferred that the highly-inclined strata of the valley of the Bormida, which agree with those of the Superga, were older than the more horizontal Subapennine marls, by which the plains of the Tanaro and the Po are skirted. At the same time, Signor Bonelli called my attention to suites of fossil shells in the museum of Turin, of species common to the Subapennine beds and to the Mediterranean; and pointed out that not only the ordinary type of the species, but even the different varieties, had their counterparts both in the fossil and recent series. I afterwards examined a beautiful collection of the tertiary shells of Italy at Parma, in the cabinets of Professor Guidotti, who computed, on a loose estimate, that there were about thirty per cent. of living species in the Subapennine beds bordering the plains of the Po. I then continued my inquiries on the same subject at Florence, Sienna, and Rome; and on my arrival at Naples, became acquainted with Signor O. G. Costa, who had examined the fossil shells of Otranto and Calabria, and had collected many recent testacea from the seas surrounding the Calabrian coasts. His comparison of the fossil and living species had led him to a very different result respecting the southern extremity of Italy, from that to which Signors Bonelli and Guidotti had arrived in regard to

the north, for he was of opinion that few of the tertiary shells were of extinct species. In confirmation of this view, he showed me a collection of fossil shells from the territory of Otranto, in which nearly all the species were recent.

I then visited the Island of Ischia, the neighbourhood of Naples, and afterwards a great part of Sicily, and was soon satisfied that in all these countries the tertiary strata contained so many shells of living species that the extinct species formed rather the exception to the general rule, whereas in the tertiary strata near Turin it was decidedly more difficult to find a recent than an extinct fossil species.

On my return to Turin, towards the close of the same year (1828), I communicated the results of my observations to Signor Bonelli, who undertook to draw up for me a comparative table of the characteristic shells common to the tertiary green-sand of the Superga, and to the strata of the south of France around Bordeaux and Dax; intending me to publish the table in my work. But the death of this amiable and zealous naturalist soon deprived me of his assistance. I had then (December, 1828) fully decided on attempting to establish four subdivisions of the tertiary epoch, considering the basin of Paris and London to be the type of the first; the beds of the Superga of the second; the Subapennine strata of northern Italy of the third; and southern Italy and the Val di Noto, in Sicily, of the fourth. I was also convinced that I had seen proofs during my tour in Auvergne, Tuscany, and Sicily, of volcanic rocks contemporary with the sedimentary strata of three, if not of all, the above periods.

On my return to Paris, in February, 1829, I communicated to M. Desnoyers some of the new views to

which my examination of Sicily had led me, and my intention to attempt a classification of the different tertiary formations in chronological order, by reference to the comparative proportion of living species of shells found fossil in each. He informed me that, during my tour, he had been employed in printing the first part of his memoir, not yet published, on "the Tertiary Formations more recent than the Paris Basin," in which he had insisted on the doctrine "of the succession of tertiary formations of different ages." At the end of the first part of his memoir, which was published before I left Paris, he annexed a note on the accordance of many of my views with his own, and he announced my intention of arranging the tertiary formations chronologically, according to the relative number of fossils in each group which were identifiable with species now living.*

At the same time I learned from M. Desnoyers, that M. Deshayes had previously, by the mere inspection of fossil shells in his extensive museum, convinced himself that the different tertiary formations might be arranged in a chronological series. I accordingly lost no time in seeing M. Deshayes, who explained to me the data on which he considered that three tertiary periods might be established, the two first of which corresponded to two of those which I was prepared to adopt (the Eocene and the Miocene), and the last embracing the Subapennine beds as distinguished from those of Bordeaux and the Superga. He had not then separated the Subapennine beds from those of Sicily, to which I have given the name of "Newer Pliocene."

* See Ann. des Sci. Nat., xvi. p. 214.

On my return to Paris in September, 1830, I studied for six weeks in the museum of M. Deshayes, examining his collection of fossil and recent shells, and profiting by his instructions in conchology. I then requested him to furnish me with lists of those species of shells which were common to two or more tertiary periods, as also the names of those known to occur both in some tertiary strata and in a living state. It was agreed that this information should be communicated in a tabular form; and after we had laboured together, and made several modifications of the plan first proposed the tables were executed by M. Deshayes, so as to appear in his name in the third volume of my first edition, published in the beginning of the year 1833. These valuable tables contained the results of the examination of no less than 8000 tertiary and recent shells, and on such data the classification adopted in this work has been principally founded. It has not been thought desirable to reprint these tables, which have already had an extensive circulation among geologists; for I was unwilling again to allot so much space to details which belong more strictly to the province of fossil chonchology.

When I published my third volume I had not studied the second volume of Professor Bronn's "Journey in Italy," published at Heidelberg in December, 1831, in which he had remarked that the distinctive character of the older as compared to the newer tertiary formations of Italy, consisted in the much smaller proportion of living species of shells found fossil in the older beds.* He had also stated, in the same volume (p.674), that the shells of the Superga beds have a nearer con-

* Brown's Reisen, &c. ii. p. 678.

nexion with those of Bordeaux than with any other tertiary formation.

To resume my classification: — the tertiary strata may be divided into four groups, in the older of which we find an extremely small number of fossils identifiable with species now living*; whereas on approaching the superior and newer sets, we find the remains of recent testacea in abundance. In no instance where we have an opportunity of observing two distinct formations in contact, the one superimposed upon the other, do we meet with an assemblage of organic remains in the uppermost differing more widely from the existing creation than the fossils of the inferior group. If there is occasionally an apparent exception to the rule, it is only where the remains belong to distinct classes of the animal kingdom; as, for example, where a deposit containing the bones of quadrupeds for the most part extinct overlies a stratum in which the imbedded shells are mostly of recent species — such exceptions seem to point to a difference in the comparative duration of species in different classes, but do not invalidate the general proposition before laid down.

Newer Pliocene period. — The latest of the four periods before alluded to is that which immediately preceded the Recent era. To this more modern period may be referred a portion of the strata of Sicily, the district round Naples, and several others to be considered in the sequel. They are characterized by a great preponderance of fossil shells referrible to species still living, and may be called the Newer Pliocene strata, the term Pliocene, or "more recent," being derived from πλειων, major, and καινος, recens, as a

* See p. 357.

large, often by far the largest, part of the fossil shells are of recent species. *

Out of 226 fossil species brought from the Sicilian beds above alluded to, M. Deshayes found that no less than 216 were of species still living, and for the most part in the Mediterranean, whereas ten only were of extinct or unknown species. I do not imagine that any of the groups referred to this period in the present work contain much more than the proportion of one in ten of extinct species of shells. Nevertheless, the antiquity of some Newer Pliocene strata of Sicily, as contrasted with our most remote historical eras, must be very great, embracing perhaps myriads of years.† There are no data for supposing that there is any break, or strong line of demarcation, between the strata and fossils of this and the Recent epoch; but, on the contrary, the monuments of the one seem to pass insensibly into those of the other.

Older Pliocene period.— The formations termed Sub-apennine in the north of Italy, and in Tuscany, contain among their fossil shells a large number which have been identified with living species. The proportion of *recent* shells usually approaches to one half. Out of 569 species examined from these strata in Italy, 238

* In this and the other names which I have adopted, it will be seen that the nomenclature has always reference to the relative proportion of recent species in the fossils of each period. In the terms Pliocene, Miocene, and Eocene, the Greek diphthongs *ei* and *ai* are changed into the vowels *i* and *e*, in conformity with the idiom of our language. My friend, the Rev. W. Whewell, to whom I have been much indebted for assisting me in inventing and anglicizing these terms, reminds me that we have Encenia, an inaugural ceremony, derived from *εν* and *καινος*, recens; and as examples of the conversion of *ei* into *i*, we have icosahedron.

† See chapters vi. vii. viii. ix.

were found to be still living, and 331 extinct or unknown. Out of 111 from the English crag, M. Deshayes determined forty-five to be recent species, and sixty-six to be extinct or unknown. The relative position of these Older Pliocene beds is explained in Fig. 64. p. 360., where they are designated by the letter *f*.

The plurality of species indicated by the name Pliocene must not in this instance be understood to imply an absolute majority of *recent* fossil shells in all cases, but a comparative preponderance whenever the Pliocene are contrasted with strata of the period immediately preceding.

Miocene period.— This antecedent tertiary epoch I shall name Miocene, or "less recent," from μειων, minor, and καινος, recens, a small minority only of fossil shells imbedded in its formations being referrible to living species. After examining 1021 Miocene shells, M. Deshayes found that 176 only were recent, being in proportion of rather more than seventeen in one hundred. As there are a certain number of fossil species which are exclusively confined to the Pliocene period, so also there are many shells equally characteristic of the Miocene. The species which pass from the Miocene into the Pliocene period, or which are common to both, are in number 196, of which 114 are living, and eighty-two extinct. The Miocene strata are largely developed in Touraine, and in the south of France near Bordeaux, in Piedmont, in the basin of Vienna, and other localities, and their relative position has been shown in Figs. 63. and 64., where they are designated by the letter *e*.

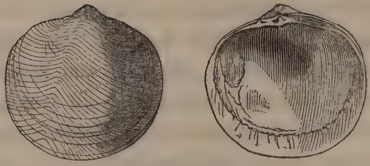
Eocene period.— The period next antecedent may be called Eocene, from ἠως, aurora, and καινος, recens, because the very small proportion of living species con-

tained in these strata indicates what may be considered the first commencement, or *dawn*, of the existing state of the animate creation. To this era the formations first called tertiary, of the Paris and London basins, are referrible. Their position is shown in Figs. 63. and 64., letter *d*, in the third chapter.

The total number of fossil shells of this period already known, when the tables of M. Deshayes, before alluded to, were constructed, was 1238, of which number forty-two only are living species, being in the proportion of nearly three and a half in one hundred. Of fossil species, not known as recent, forty-two were found to be common to the Eocene and Miocene epochs.

The present geographical distribution of those recent species which are found fossil in formations of such high antiquity as those of the Paris and London basins, is a subject of the highest interest. In the more modern formations, where so large a proportion of the fossil shells belong to species still living, they also belong, for the most part, to species now inhabiting the seas immediately adjoining the countries where they occur fossil; whereas the recent species, found in the older tertiary strata, are frequently inhabitants of distant latitudes, and usually of warmer climates. Of the forty-two Eocene species, or those found in the earliest tertiary strata, which occur fossil in England, France, and Belgium, and are at the same time still living, about half now inhabit the seas within or near the tropics, and almost all the rest are inhabitants of the more southern and warmer parts of Europe. If some Eocene species still flourish in the same latitudes where they are found fossil, they are species which, like *Lucina divaricata*, are now found in many seas,

Fig. 65.

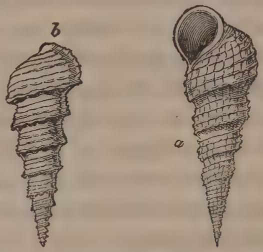


Lucina divaricata.

even those of very distant quarters of the globe; and this wide geographical range indicates a capacity of enduring a variety of external circumstances, which may enable a species to survive considerable changes of climate and other revolutions of the earth's surface. One fluviatile species (*Melania inquinata*), fossil in the

Fig. 66.

a Variety from the Soissonnais which resembles the recent.
b Tuberculated variety.



Melania inquinata as found fossil in Paris basin. One third less than natural size.

Paris basin, is now known only in the Philippine Islands; and, during the lowering of the temperature of certain parts of the earth's surface, may perhaps have escaped destruction by migrating to the south. I have pointed out in the third book how rapidly the eggs of freshwater species might, by the instrumentality of water-fowl, be transported from one region to another.* Other Eocene species, which still survive

* See p. 78.

and range from the temperate zone to the equator, may formerly have extended from the pole to the temperate zone; and what was once the southern limit of their range may now be the most northern.

Even if geologists had not established several remarkable facts in attestation of the longevity of certain tertiary species, we might still have anticipated that the duration of the living species of aquatic and terrestrial testacea would be very unequal. For it is clear that those which have a wide range, and inhabit many different regions and climates, may survive the influence of destroying causes, which might extirpate the greater part of species at present their contemporaries. The increase of existing species, and gradual disappearance of the extinct, as we trace the series of formations from the older to the newer, is somewhat analogous, as was before observed, to the fluctuations of a population such as might be recorded at successive periods, from the time when the oldest of the individuals now living was born to the present moment; and those Eocene testacea which still flourish may be said to have outlived several successive states of the organic world, just as Nestor survived three generations of men.

It appears, then, that the numerical proportion of recent to extinct species of fossil shells in the different tertiary periods may be thus expressed. — In the

Newer Pliocene period about	90 to 95	per cent. of *recent* fossils.*
Older Pliocene period . . .	35 to 50	
Miocene period	17	
Eocene period	$3\frac{1}{2}$	

* The new terms may be remembered by *Pli*ocene recalling *Pl*us, *more;* *Mi*ocene, *Mi*nus, *less;* and *E*ocene, the *E*ast, or dawn.

These numbers, however, must be regarded merely as the results obtained from a careful examination of the first groups which chance has thrown in our way, or which lie in the most accessible parts of Europe.

The distribution of the fossil species from which the above results were obtained by M. Deshayes was as follows: —

In the formations of the Pliocene periods, older and newer	777
In the Miocene	1021
In the Eocene	1238
	3036

Only seventeen species of shells were found to be common to the three epochs, which may therefore be said to characterize the entire tertiary formations of Europe. Thirteen of them are species still living, while four are known only as fossil. The thirteen living species are —

1. Dentalium entalis.
2. ——— strangulatum.
3. Fissurella græca.
4. Bulla lignaria.
5. Rissoa cochlearella.
6. Murex fistulosus.
7. ——— tubifer.
8. Polymorphina gibba.
9. Triloculina oblonga.
10. Lucina divaricata.
11. ——— gibbosula.
12. Isocardia cor.
13. Nucula margaritacea.

The four extinct species are—

1. Dentalium coarctatum.
2. Tornatella inflata.
3. Bulimus terebellatus.
4. Corbula complanata.

In thus selecting the proportional number of recent to extinct species of shells as a useful term of comparison for successive tertiary groups, or as one from which a convenient nomenclature may be derived, I

have no wish to exalt the mere per-centage of living species of fossil shells into the leading characteristic of each group. The Eocene strata of Paris and London, for example, are marked by the presence of a vast variety of peculiar *extinct* species of testacea, as well as of other animal and vegetable remains, in comparison of which the proportion of living species is a character of subordinate importance. At the same time it should be observed, that had the geologist collected the fossils of the crag of Norfolk, the blue clay of London, and the coarse white limestone of Paris, and then considered these formations merely with reference to the number of recent shells contained in each, he would have seen, by this character alone, that the Parisian and London strata differed widely from the crag, and agreed very closely with each other. Afterwards, on extending his examination to the *extinct* species, he would find that those of the Paris and London formations also corresponded, and formed together an assemblage very distinct from the *extinct* species in the crag. In this and many other cases where our zoological investigations are far advanced, a reference to the proportion of recent species would lead to the same general classifications, as the mere consideration of extinct testacea in different tertiary formations.

Many geologists are desirous of connecting divisions such as those above pointed out with sudden and violent interruptions to the ordinary course of events, and they regard them as indicative of successive changes in the organic world, accompanying revolutions equally important in the physical geography of the earth's surface. But I have already attempted to show, that such apparent breaks in the geological series may be accounted for partly by the mode in which the com-

memorative processes operate, partly by the removal of strata by denudation, and that they arise, in part, from the small progress which we have hitherto made in the discovery and study of such deposits as are preserved.*

From the experience of the last few years, we may anticipate the discovery of many intermediate gradations between the boundary lines first drawn; and if formations are brought to light intervening between the Eocene and Miocene, or between those of the last period and the Pliocene, we may still find an appropriate place for all, by forming subdivisions, on the same principle as that which has determined the separation of the lower from the upper Pliocene groups. Thus, for example, we might have three divisions of the Eocene epoch, — the older, middle, and newer; and three similar subdivisions, both of the Miocene and Pliocene epochs. In that case, the formations of the middle period must be considered as the types from which the assemblage of organic remains in the groups on both sides will diverge.

When we institute a new genus in natural history, and intend it to occupy a place intermediate between two genera previously established, as the genus B, for example, between A and C, we select a particular species *b*, as the generic type of B, and then determine to refer all other species to the same genus, provided they approach nearer to *b* than the types of A or C. On comparing together the species of B, we discover that they deviate in various ways and degrees from the typical species, some of them approaching somewhat nearer to the characters of the genus A

* See p. 367.

which precedes, others to C which stands next, in the series. By due attention to these shades of difference we may arrange all the congeners in order, according to their natural affinities.

In like manner, when we desire to class geological formations in a chronological series, we may select a certain set of strata as *b*, and consider it as typical of a particular period B. We may then refer other formations to B, if they resemble in their organic contents the normal group *b* more nearly than the types of the antecedent or subsequent epochs A and C. And we may consider the strata which in departing slightly from *b* approximate to A as being the older divisions of the period B, and those which depart from the type *b* in the direction of C as the newer deposits of the same era.

In determining originally the order of succession of A, B, and C, we must be guided, as far as possible, by the evidence of superposition by which the relative age of the principal groups may generally be decided with certainty.

It must not be inferred from any thing above advanced, that the fourfold division of the tertiary epoch is purely arbitrary, or that any other number of periods might in the present state of the science have been chosen with equal propriety. For, though it be true that zoological periods in geology, like genera and orders in Natural History, are purely artificial divisions; yet we have at present no alternative but to accept those lines of separation which we find in the series of monuments first brought to light.

It is a comparatively easy task to establish genera in departments of zoology and botany which have been enriched with only a small number of species, and

where there is as yet no tendency in one set of characters to pass almost insensibly, by a multitude of connecting links, into another. So, in geology, our facilities of systematic arrangement are perhaps greater now than they will be hereafter, when we shall be under the necessity of intercalating new periods between those first established.

In conclusion, I may observe, that although the lapse of ages comprised within a single period is very much narrowed by the fourfold subdivision above explained, yet when all the Eocene or Miocene deposits are said to be *contemporaneous*, this term must be received with a good deal of latitude. Considerable intervals of time may have elapsed without giving rise to any marked distinction in the imbedded organic remains.

Suppose the growth of the delta of the Nile to cease from this moment, and some new river to begin to transport sediment into the Mediterranean at any other point, and to form a delta in the course of many thousand years, this last formation might contain the same fossils as the marine and fluviatile deposits of the Nile previously accumulated in Lower Egypt; the difference at least might be so trifling that future geologists would regard them as contemporaneous, if they followed the same rules of classification as those laid down in this chapter.

The recent strata form a common point of departure in all countries. — We derive one great advantage from beginning our classification of formations by a comparison of the fossils of the more recent strata with the species now living; namely, the acquisition of a common point of departure in every region of the globe. Thus, for example, if strata should be discovered in

India or South America, containing the same small proportion of recent shells as are found in the Paris basin, *they* also might be termed Eocene; and, on analogous data, an approximation might be made to the relative dates of strata placed in the arctic and tropical regions, or the comparative age might be ascertained of European deposits and those at the antipodes. There might be no species common to the two groups; yet we might make some approach, perhaps a near one, towards determining their relative age from the common relation which they bear to the existing state of the animate creation. We may afterwards avail ourselves of the dates thus established, as eras to which the monuments of preceding periods may be referred.

Mammiferous remains of successive tertiary eras.— But although a thirtieth part of the Eocene testacea have been identified with species now living, none of the associated mammiferous remains belong to species which now exist, either in Europe or elsewhere. Some of these equalled the horse, and others the rhinoceros, in size; and they could not possibly have escaped observation, had they survived down to our time. More than forty of these Eocene mammifers are referrible to a particular division of the order Pachydermata, which has now only four living representatives on the globe, namely, three tapirs and the Daman of the Cape. Of those forty fossil species, even the genera are distinct from any which have been established for the classification of living animals.

In the Miocene mammalia we find a few of the generic forms most frequent in the Eocene strata associated with some of those now existing, and in the Pliocene we find an intermixture of extinct and recent species of quadrupeds. There is, therefore,

a considerable degree of accordance between the results deducible from an examination of the fossil testacea, and those derived from the mammiferous fossils. But although the latter are more important in respect to the unequivocal evidence afforded by them of the extinction of species, yet, for reasons before explained, they are of comparatively small value in the general classification of strata in geology.*

We have seen that the imbedding of mammiferous remains depends on rare casualties, and that they are, for the most part, preserved in detached alluvium covering the emerged land, or in osseous breccias and stalagmites formed in caverns and fissures, or in isolated lacustrine formations.† Such fissures and caves may probably have remained open during successive geological periods; and the alluvions, spread over the surface, may have been disturbed again and again, until the mammalia of successive epochs were mingled and confounded together. Hence we must be careful, when we endeavour to refer the remains of mammalia to certain tertiary periods, that we ascertain, not only their association with testacea of which the date is known, but, also, that the remains were intermixed in such a manner as to leave no doubt of the former co-existence of the species.

In the next page will be found a Synoptical Table of the Recent and Tertiary Formations alluded to in this and the following chapters.

* See p. 380. † Book iii. chaps. xiii. and xiv.

Synoptical Table of Recent and Tertiary Formations.

PERIODS.		Character of Formations.	Localities of the different Formations.
I. Recent.	. . . . .	Marine.	Coral formations of Pacific. Delta of Po, Ganges, Mississippi.
		Freshwater.	Modern deposits in Lake Superior — Lake of Geneva — Marl lakes of Scotland — Italian travertin.
		Volcanic.	Jorullo — Monte Nuovo — Modern lavas of Iceland, Etna, Vesuvius.
II. Tertiary.	1. Newer Pliocene.	Marine.	Strata of the Val di Noto in Sicily. Ischia.
		Freshwater.	Valley of the Elsa around Colle in Tuscany.
		Volcanic.	Older parts of Vesuvius, Etna, and Ischia — Volcanic rocks of the Val di Noto in Sicily.
	2. Older Pliocene.	Marine.	Northern Subapennine formations, as at Parma, Asti, Sienna, Perpignan, Nice — English Crag.
		Freshwater.	Alternating with marine beds near the town of Sienna.
		Volcanic.	Volcanos of Tuscany and Campagna di Roma.
	3. Miocene.	Marine.	Strata of Touraine, Bordeaux, Valley of the Bormida, and the Superga near Turin — Basin of Vienna.
		Freshwater.	Alternating with marine at Saucats, twelve miles south of Bordeaux.
		Volcanic.	Hungarian and Transylvanian volcanic rocks. Part of the volcanos of Auvergne, Cantal, and Velay?
	4. Eocene.	Marine.	Paris and London Basins.
		Freshwater.	Alternating with marine in Paris basin — Isle of Wight — purely lacustrine in Auvergne, Cantal, and Velay.
		Volcanic.	Oldest part of volcanic rocks of Auvergne.

CHAPTER VI.

NEWER PLIOCENE FORMATIONS — SICILY.

Reasons for considering, in the first place, the more modern periods — Geological structure of Sicily — Formations of the Val di Noto — Divisible into three groups — Great limestone — Schistose and arenaceous limestone — Blue marl with shells — Strata subjacent to the above — Volcanic rocks of the Val di Noto (p. 411.) — Dikes — Tuffs and Peperinos — Volcanic conglomerates — Proofs of long intervals between volcanic eruptions — Dip and direction of Newer Pliocene strata of Sicily.

Having endeavoured, in the last chapter, to explain the principles on which the different tertiary formations may be arranged in chronological order, I shall now proceed to consider in detail the newest division, or that which, from its containing the greatest proportion of recent shells of any of the four tertiary groups, has been named the Newer Pliocene.*

It may appear, that I reverse the natural order of historical research by thus describing, in the first place, the monuments of a period which immediately preceded our own era, and then passing to the events of antecedent ages. But, in the present state of geological science, this retrospective order of inquiry is the only one which can conduct us gradually from the known to the unknown, from the simple to the more complex phenomena. I have already explained my

* See pp. 390. and 395.


MAP
of Part of
SICILY
14 30
15
38
37
Capo Milazzo
Milazzo
Capo Calva
Patti
St. Lucia
VAL DI DEMONE
Mojo
Randazzo
Mt. Etna
Caltabiano
Traino
R. Simeto
R. Salso
Adorno
Aci Castello
Trezza
Cyclopian Is.
Castrogiovanni
R. Dittaino
Paterno
Misterbianco
CATANIA
Plain of Catania
R. Simeto
R. Gurna Luga
Piazza
Palagonia
L. Biveri
Villasmundo
C. St. Croce
Militello
Lentini
Augusta
Caltagirone
Grammichele
Vizzini
Melilli
Sortino
VAL DI NOTO
Pentalica
SYRACUSE
Floridia
Terranova
R. Dirillo
Chiaramonte
Vittoria
Noto
Ragusa
Modica
R. Ragusa
Spaccaforno
Pachino
C. Passero
Pt. delle Correnti
1
Volcanic
2
Newer Pliocene
3
Newer Pliocene Alternating with Volcanic

reasons for commencing with an examination, in the last two books, of the events of the *recent* epoch, from which the greater number of rules of interpretation in geology may be derived. The formations of the Newer Pliocene period will be considered next in order, because these have undergone the least degree of alteration, both in position and internal structure, subsequently to their origin. They are monuments of which the characters are more easily deciphered than those belonging to more remote periods, for they have been less mutilated by the hand of time. The organic remains, more especially of this era, are most important, not only as being in a more perfect state of preservation, but also as being chiefly referrible to species now living; so that their habits are known to us by direct comparison, and not merely by inference from analogy, as in the case of extinct species.

Geological structure of Sicily.—I shall first describe an extensive district in Sicily, where the Newer Pliocene strata are largely developed, and where they are raised to considerable heights above the level of the sea. After presenting the reader with a view of these formations, I shall endeavour to explain the manner in which they originated, and shall speculate on the subterranean changes of which their present position affords evidence.

The island of Sicily consists partly of primary and secondary rocks, which occupy, perhaps, about two thirds of its superficial area; and the remaining part is covered by tertiary formations, which are of great extent in the southern and central parts of the island, while portions are found bordering nearly the whole of the coasts.

Formations of the Val di Noto.—If we first turn

our attention to the Val di Noto (see map, Pl. VII.), a district which intervenes between Etna and the southern promontory of Sicily, we find a considerable tract, containing within it hills which are from one to two thousand feet in height, entirely composed of limestone, marl, sandstone, and associated volcanic rocks, which belong to the Newer Pliocene era. The recent shells of the Mediterranean abound throughout the sedimentary strata, and there are abundant proofs that the igneous rocks were the produce of successive submarine eruptions, repeated at intervals during the time when the subaqueous formations were in progress.

These rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata whereon it rests, by the low level plain of Catania, just elevated above the level of the sea, and watered by the Simeto. The traveller who passes from Catania to Syracuse has an opportunity of observing, on the sides of the valley, many deep sections of the modern formations above described, especially if he makes a slight detour by Sortino and the valley of Pentalica.

The whole series of strata, in the Val di Noto, is divisible into three principal groups, exclusive of the associated volcanic rocks. The uppermost mass consists of limestone, which sometimes acquires the enormous thickness of seven or eight hundred feet, below which is a series much inferior in thickness, consisting of a calcareous sandstone, conglomerate and schistose limestone, and beneath this again blue marl. The whole of the above groups contain shells and zoophytes, nearly all of which are referrible to species now inhabiting the contiguous sea.

Great limestone formation (*a*, Fig. 67.).—In mineral character this rock often corresponds to the yellowish

white building-stone of Paris, well known by the name of *Calcaire grossier*, but it often passes into a much more compact stone. In the deep ravine-like valleys of Sortino and Pentalica, it is seen in nearly horizontal strata, as solid and as regularly bedded as the greater part of our ancient secondary formations. It abounds in natural caverns, which, in many places, as in the valley of Pentalica, have been enlarged by artificial excavations.

Fig. 67. Syracuse. Girgenti.

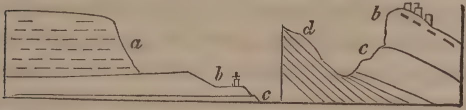
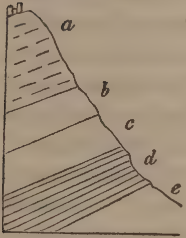


Fig. 68.



Castrogiovanni.

a. Great limestone of Val di Noto.
b. Schistose and arenaceous limestone of Floridia.
c. Blue marl with shells.
d. White laminated marl.
e. Blue clay and gypsum, without shells.

The shells in the limestone are often very indistinct, sometimes nothing but casts remaining; but in many localities, especially where there is a slight intermixture of volcanic sand, they are more entire, and, as I have already stated, can almost all be identified with recent Mediterranean testacea. Several species of the genus Pecten are exceedingly numerous, particularly the large scallop (*P. Jacobæus*), now so common on the coasts of Sicily. The shells which I collected from this limestone at Syracuse, Villasmonde, Militello (V. di Noto), and Girgenti, have been examined by M.

Deshayes, and found, with three or four exceptions, to be all referrible to species now living.*

The mineral characters of this great calcareous formation vary considerably in different parts of the island. In the south near the town of Noto, the rock puts on the compactness, together with the spheroidal concretionary structure, of some of the Italian travertins. At the same place, also, it contains the leaves of plants and reeds, as if a stream of fresh water, charged with carbonate of lime and terrestrial vegetable remains, had entered the sea in the neighbourhood. At Spaccaforno, and other places in the south of Sicily, a similar compact variety of the limestone occurs, where it is for the most part pure white, often very thick bedded, and occasionally without any lines of stratification. This hard white rock is often four or five hundred feet in thickness, and appears to contain no fossil shells. It has much the appearance of having been precipitated from the waters of mineral springs, such as frequently rise up at the bottom of the sea in the volcanic regions of the Mediterranean. As these springs give out an equal quantity of mineral matter at all seasons, they are much more likely to give rise to unstratified masses, than a river which is swoln and charged with sedimentary matter of different kinds, and in unequal quantities, at particular seasons of the year.

* I procured at Villasmonde, seven species; at Militello, ten; in the limestone of Girgenti, of which the ancient temples are built, ten species; from the limestone and subjacent clay at Syracuse, twenty-six species; in the limestone and clay near Palermo, also belonging to the Newer Pliocene formation, one hundred species, the names of which were published in Appendix II. of the octavo edition.

The great limestone, above mentioned, prevails not only in the Val di Noto, but reappears in the centre of the island, capping the hill of Castrogiovanni, at the height of three thousand feet above the level of the sea. It is cavernous there, as at Sortino and Syracuse, and contains fossil shells and casts of shells of the same species.*

Schistose and arenaceous limestone, &c. (*b.* Fig. 67.).—The limestone above mentioned passes downwards into a white calcareous sand, which has sometimes a tendency to an oolitic and pisolitic structure, analogous to that before described when speaking of the travertin of Tivoli.† At Floridia, near Syracuse, it contains a sufficient number of small calcareous pebbles to constitute a conglomerate, where also beds of sandy limestone are associated, replete with numerous fragments of shells, and much resembling, in structure, the English corn-brash. A diagonal lamination is often observable in the calcareous sandy beds analogous to that represented in the first volume (p. 374. Fig. 10.), and to that exhibited in many sections of the English crag.‡

In some parts of Sicily, this sandy calcareous division, *b*, seems to be represented by yellow sand, exactly resembling that so frequently superimposed on the blue shelly marl of the Subapennines in the Italian peninsula. Thus, near Grammichele, on the road to Caltagirone, beds of incoherent yellow sand, several hundred feet in thickness, with occasional

* Dr. Daubeny correctly identified the Val di Noto limestone of Syracuse with that of the summit of Castrogiovanni.—Jameson, Ed. Phil. Journ., No. xxv. p. 107. July, 1825.

† Vol. I. p. 318. ‡ See chap. xiii.

layers of shells, repose upon the blue shelly marl of Caltagirone.

When we consider the arenaceous character of this formation, the disposition of the laminæ, and the broken shells sometimes imbedded in it, it is difficult not to suspect that it was formed in shallower water, and nearer the action of superficial currents, than the superincumbent limestone, which was evidently accumulated in a sea of considerable depth. If we adopt this view, we must suppose a subsidence of the bed of the sea, subsequent to the deposition of the arenaceous beds in the Val di Noto.

Blue marl with shells (*c*, Figs. 67, 68.).—Under the sandy beds, last mentioned, is found an argillaceous deposit of variable thickness, called *Creta* in Sicily. It resembles the blue marl of the Subapennine hills, and, like it, encloses fossil shells and corals in a beautiful state of preservation. Of these I collected a great abundance from the clay, on the south side of the harbour of Syracuse, and twenty species in the environs of Caltanisetta, all of which, with three exceptions, M. Deshayes was able to identify with recent species. From similar blue marl, alternating with yellow sand, at Caltagirone, at an elevation of about 500 feet above the level of the sea, I obtained forty species of shells, of which all but six were recognized as identical with recent species.* The position of this argillaceous formation is well seen at Castrogiovanni and Girgenti, as represented in the sections, Figs. 67, 68. In both of these places, the limestone of the

* Lists of these shells were given in Appendix II. of the first, or octavo edition.

Val di Noto reappears, passing downwards into a calcareous sandstone, below which is a shelly blue clay.

Strata beneath the blue marl. — The clay rests, in both localities, on an older series of white and blue marls, probably belonging to the tertiary period, but of which I was unable to determine the age, having procured from it no organic remains save the skeletons of fish, all of extinct species, which I found in the white thinly laminated marls.*

These marls are sometimes gypseous, and belong to a great argillaceous formation which stretches over a considerable part of Sicily, and contains sulphur and salt in great abundance. The strata of this group have been in some places contorted in the most extraordinary manner, their convolutions often resembling those seen in the most disturbed districts of primary clay slate.

But I wish, at present, to direct the reader's exclusive attention to strata decidedly referrible to the Newer Pliocene era, and I have yet to mention the igneous rocks associated with the sedimentary formations already alluded to.

Volcanic rocks of the Val di Noto. — The volcanic rocks occasionally associated with the limestones, sands, and marls already described, constitute a very prominent feature throughout the Val di Noto. Great confusion might have been expected to prevail, where lava and ejected sand and scoriæ are intermixed with the marine strata, and, accordingly, we find it often

* I found these fossil fish in great abundance on the road, half a mile north-west of Radusa, on my way to Castrogiovanni, where the marls are fetid; and near Castrogiovanni in gypseous marls, at the mile-stone No. 88., and between that and No. 89.

impossible to recognize the exact part of the series to which the beds thus interfered with belong.

Sometimes there are proofs of the posterior origin of the lava, and sometimes of the newer date of the stratified rock, for we find dikes of lava intersecting both the marl and limestone, while, in other places, calcareous beds repose upon lava, and are unaltered at the point of contact. Thus the shelly limestone of Capo Santa Croce rests in horizontal strata upon a mass of lava, which had evidently been long exposed to the action of the waves, so that the surface has been worn perfectly smooth. The limestone is unchanged at its junction with the igneous rock, and incloses within it pebbles of the lava.*

The volcanic formations of the Val di Noto usually consist of the most ordinary variety of basalt, with or without olivine. The rock is sometimes compact, often very vesicular. The vesicles are occasionally empty, both in dikes and currents, and are in some localities filled with calcareous spar, arragonite, and zeolites. The structure is, in some places, spheroidal; in others, though rarely, columnar. I found dikes of amygdaloid, wacke, and prismatic basalt, intersecting the limestone at the bottom of the hollow called Gozzo degli Martiri, below Melilli.

Dikes.—Dikes of vesicular and amygdaloidal lava are also seen traversing peperino, west of Palagonia, near a mill by the road side.

In these cases we may suppose the peperino to have resulted from showers of volcanic sand and scoriæ, together with fragments of limestone thrown out by a submarine explosion, similar to that which lately

* This locality is described by Professor Hoffmann, Archiv für Mineralogie, &c. Berlin, 1831.

gave rise to the volcanic island off Sciacca. When the mass was, to a certain degree, consolidated, it may have been rent open, so that the lava ascended through fissures, the walls of which were perfectly even and parallel. After the melted matter that filled the rent in No. 69. had cooled down, it must have been fractured and shifted horizontally by a lateral movement.

Fig. 69.

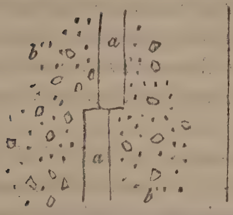
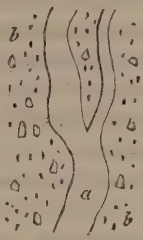


Fig. 70.



Horizontal section of dikes near Palagonia.

a. Lava.

b. Peperino, consisting of volcanic sand, mixed with fragments of lava and limestone.

In the second figure, No. 70., the lava has more the appearance of a vein which forced its way through the peperino, availing itself, perhaps, of a slight passage opened by rents caused by earthquakes. Some of the pores of the lava, in these dikes, are empty, while others are filled with carbonate of lime.

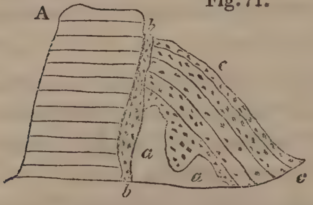
The annexed diagrams (Figs. 69. and 70.) represent a ground plan of the rocks as they are exposed to view on a horizontal surface. It is highly probable that similar appearances would be seen, if we could examine the floor of the sea in that part of the Mediterranean where the waves have recently washed away the new volcanic island; for when a superincumbent mass

of ejected fragments has been removed by denudation, we may expect to see sections of dikes traversing tuff, or, in other words, sections of the channels of communication by which the subterranean lavas reached the surface.*

On the summit of the limestone platform of the Val di Noto I more than once saw analogous dikes, not only of lava but of volcanic tuff, rising vertically through the horizontal strata, and having no connection with any igneous masses now apparent on the surface. In regard to the *dikes of tuff or peperino*, we may suppose them to have been open fissures at the bottom of the sea, into which volcanic sand and scoriæ were drifted by a current.

Tuffs and peperinos. — In the hill of Novera, between Vizzini and Militelli, a mass of limestone, horizontally stratified, comes in contact with inclined strata of tuff (see Fig. 71.); while a mixed calcareous and

Fig. 71.



A. Limestone.
aa. Calcareous breccia with fragments of lava.
b. Black tuff.
c. Tuff.

volcanic breccia, *a a*, supports the inclined layers of tuff, *c*. The vertical fissure, *b b*, is filled with volcanic sand of a different colour. An inspection of this section will convince the reader that the limestone must have been greatly dislocated during the period of the submarine eruptions.

At the town of Vizzini a dike of lava intersects the

* See Vol. II. p. 203.

argillaceous strata, and converts them into siliceous schist, which has been contorted and shivered into an immense number of fragments.

I have stated that the beds of limestone, clay, and sand, in the Val di Noto, are often partially intermixed with volcanic ejections, such as may have been showered down into the sea during eruptions, or may have been swept by rivers from the land. When the volcanic matter predominates, these compound rocks constitute the peperinos of the Italian mineralogists, some of which are highly calcareous, full of shells, and extremely hard, being capable of a high polish like marble. In some parts of the Val di Noto they are variously mottled with spots of red and yellow, and contain small angular fragments, similar to the lapilli thrown from volcanos.

It is recorded that, during the eruption of Graham Island off the southern coast of Sicily, the sea was in a state of violent ebullition, and filled for several weeks continuously with red or chocolate-coloured mud, consisting of finely comminuted scoriæ.* During this period, it is clear that the waves and currents that have since had power to sweep away the island, and disperse its materials far and wide over the bed of the sea, must with still greater ease have carried to vast distances the fine red mud, which was seen boiling up from the bottom, so that it may have entered largely into the composition of modern peperinos.

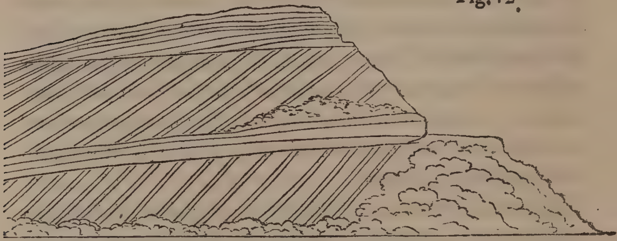
Professor Hoffmann relates that, during the eruption, (June 1831,) the surface of the sea was strewed over, at the distance of thirty miles from the new volcano, with so dense a covering of scoriæ, that the fishermen were obliged to part it with their oars, in order to

* Vol. II. p. 200.

propel their boats through the water. It is, therefore, quite consistent with analogy, that we should find the ancient tuffs and peperinos so much more generally distributed than the submarine lavas.

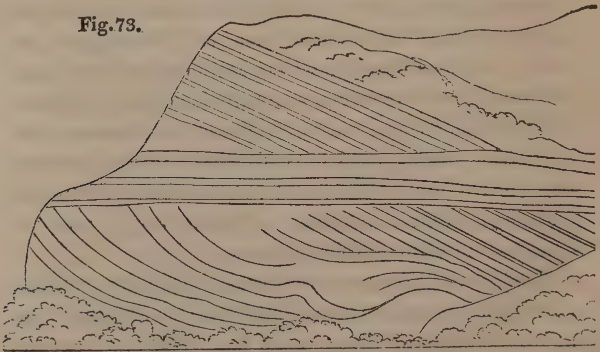
In the road which leads from Palagonia to Lago Naftia, and at the distance of about a mile and a half from the former place, there is a small pass where the hills, on both sides, consist of a calcareous grit, intermixed with some grains of volcanic sand.

Fig. 72.



Section of calcareous grit and peperino, east of Palagonia. South side of pass Vertical height about thirty feet.

Fig. 73.



Section of the same beds on the north side of the pass.

The disposition of the strata, on both sides of the pass, is most singular, and remarkably well exposed,

as the harder layers have resisted the weathering of the atmosphere and project in relief. The sections exhibited on both sides of the pass are nearly vertical, and do not exactly correspond, as will be seen in the annexed diagrams (Figs. 72. and 73.) It is somewhat difficult to conceive in what manner this arrangement of the layers was occasioned; but we may, perhaps, suppose it to have arisen from the throwing down of calcareous sand and volcanic matter, upon steep slanting banks at the bottom of the sea, in which case they might have accumulated at various angles of between thirty and fifty degrees, as may be frequently seen in the sections of volcanic cones in Ischia and elsewhere. The denuding power of the waves may, then, have cut off the upper portion of these banks; so that nearly horizontal layers may have been superimposed unconformably, after which another bank may have been formed in a similar manner to the first.

Volcanic conglomerates.—In the Val di Noto we sometimes meet with conglomerates entirely composed of volcanic pebbles. They usually occur in the neighbourhood of masses of lava, and may, perhaps, have been the shingle produced by the wasting cliffs of small islands in a volcanic archipelago. The formation of similar beds of volcanic pebbles may now be seen in progress on the beach north of Catania, where the waves are undermining one of the modern lavas of Etna; and the same may also be seen on the shores of Ischia.

Proofs of gradual accumulation.—In one part of the great limestone formation near Lentini, I found some imbedded volcanic pebbles, covered with full-grown serpulæ, supplying a beautiful proof of a con-

siderable interval of time having elapsed between the rounding of these pebbles and their inclosure in a solid stratum. I also observed, not far from Vizzini, a very striking illustration of the length of the intervals which occasionally separated the distinct lava currents. A bed of oysters, perfectly identifiable with our common eatable species, no less than *twenty feet in thickness*, is there seen resting upon a current of basaltic lava; upon the oyster-bed again is superimposed a second mass of lava, together with tuff or peperino. Near Galieri, not far from the same place, a horizontal bed, about a foot and a half in thickness, composed entirely of a common Mediterranean coral (*Caryophyllia cespitosa*, Lam.), is also seen in the midst of the same series of alternating igneous and aqueous formations. These corals stand erect as they grew; and after being traced for hundreds of yards, are again found at a corresponding height on the opposite side of the valley.

Dip and direction.—The disturbance which the Newer Pliocene strata have undergone in Sicily, subsequent to their deposition, varies greatly in degree in different places; in general, however, they are nearly horizontal, and are not often highly inclined. The calcareous schists, on which part of the town of Lentini is built, are much fractured, and dip at an angle of twenty-five degrees to the north-west. In some of the valleys in the neighbourhood an anticlinal dip is seen, the beds on one side being inclined to the north-west, and on the other to the south-east.

Throughout a considerable part of Sicily which I examined, the dips of the tertiary strata were north-east and south-west; as, for example, in the district

included between Terranuova, Girgenti, Caltanisetta, and Piazza, where there are several parallel lines, or ridges of elevation, which run from north-west to south-east.*

* I have reprinted this chapter without additions, and almost without alterations, nearly as I wrote it soon after my tour in Sicily, in 1828. But we may shortly expect a fuller account of the geology of Sicily from Professor Hoffmann of Berlin, who has devoted more than a year to its examination.

CHAPTER VII.

NEWER PLIOCENE FORMATIONS — ETNA.

Marine and volcanic formations at the base of Etna — Their connection with the strata of the Val di Noto — Bay of Trezza — Cyclopian isles — Fossil shells of recent species (p. 425.) — Basalt and altered rocks in the Isle of Cyclops — Internal structure of the cone of Etna — Val di Calanna (p. 434.) — Val del Bove not an ancient crater — its precipices intersected by countless dikes — Scenery of the Val del Bove — Form, composition, and origin of the dikes (p. 440.) — Lavas and breccias intersected by them.

The phenomena considered in the last chapter suggest many theoretical views of the highest interest in geology; but before entering upon these topics I am desirous of describing some analogous formations in Valdemone.

If the traveller passes along the table-land, formed by the great limestone of the Val di Noto, until it terminates suddenly near Primosole, he there sees the plain of Catania at his feet; and before him, to the north, the cone of Etna (see Fig. 74.). At the base of the cone he beholds a low line of hills, *e e*, formed of clays and marls, associated with yellowish sand, similar to the formation provincially termed "Creta," in various parts of Sicily.*

This marine formation, which is composed partly of

* See Creta, before described, p. 410.

Fig. 74.

View of Etna from the summit of the limestone platform of Primosole.

a. Highest cone. *b.* Montagnuola.
c. Monte Minardo, with smaller lateral cones above.
d. Town of Licodia dei Monaci.
e. Marine formation called creta, argillaceous and sandy beds with a few shells, and associated volcanic rocks.
f. Escarpment of stratified subaqueous volcanic tuff, &c., north-west of Catania.
g. Town of Catania.
h. i. Dotted line expressing the highest boundary along which the marine strata are occasionally seen. *k.* Plain of Catania.
l. Limestone platform of Primosole of the Newer Pliocene.
m. La Motta di Catania.

volcanic and partly of sedimentary rocks, is seen to lie below the modern lavas of Etna. To what extent it forms the base of the mountain cannot be observed, for want of sections of the lower part of the cone; but the marine sub-Etnean beds are not seen to rise to a greater elevation than eight hundred, or, at the utmost, one thousand, feet above the level of the sea. The annexed drawing is not a section, but an outline view of Etna, as seen from Primosole; so that the proportional height of the volcanic cone, which is, in reality, ten times greater than that of the hills of "Creta," at

its base, is not expressed, the summit of the cone being ten or twelve miles more distant from the plain of Catania than Licodia.

Connection of the sub-Etnean strata with those of the Val di Noto.—These marine strata are found both on the southern and eastern foot of Etna, and it is impossible not to infer that they belong to the inferior argillaceous series of the Val di Noto, which they resemble both in mineral and organic characters. In one locality they appear on the opposite sides of the Valley of the Simeto, covered on the north by the lavas of Etna, and on the south by the Val di Noto limestone.

Val di Noto. Fig. 75. Etna.

Section from Paternò by Lago di Naftia to Palagonia.

a. Plain of the Simeto.
b. Base of the cone of Etna, composed of modern lavas.
c. Limestone of the Val di Noto.
d. Clay, sand, and associated submarine volcanic rocks.

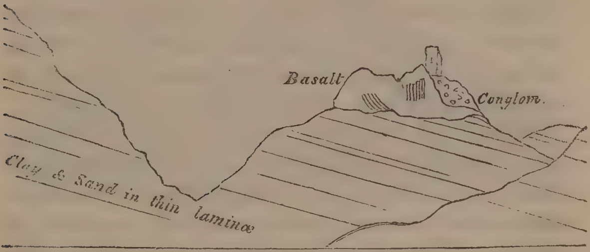
If in the country adjacent to the Lago di Naftia, through which the annexed section is drawn, and in several other districts where the "creta" prevails, together with associated submarine lavas, and where there is no limestone capping, a volcano should now burst forth, and give rise to a great cone, the position of such a cone would exactly correspond to that of the modern Etna, with relation to the rocks on which it rests.

Southern base of Etna.—The marine strata of clay and sand already alluded to, alternate in thin layers at

the southern base of Etna, sometimes attaining a thickness of three hundred feet, or more, without any intermixture of volcanic matter. Crystals of selenite are dispersed through the clay, accompanied by a few shells, almost entirely of recent Mediterranean species. This formation of blue marl and yellow sand greatly resembles in character that of the Italian Subapennine beds, and, like them, often presents a surface denuded of vegetation, in consequence of the action of the rains on soft incoherent materials.

In travelling by Paternò, Misterbianco, and La Motta, we pass through deep narrow valleys excavated through these beds, which are sometimes capped, as at La Motta, by columnar basalt, accompanied by strata of tuff and volcanic conglomerate. (Fig. 76.)

Fig. 76.



La Motta, near Catania.

The conglomerate is here composed of rolled masses of basalt, which may have originated either when first the lava was produced in a volcanic archipelago, or subsequently when the whole country was rising from beneath the level of the sea. Its occurrence in this situation is striking, as not a single pebble can be observed in the entire thickness of subjacent beds of sand and clay.

The dip of the marine strata, at the base of Etna, is

by no means uniform; on the eastern side, for example, they are sometimes inclined towards the sea, and at others towards the mountain. Near the aqueduct at Adernò, on the southern side, I observed two sections, in quarries not far distant from each other, where beds of clay and yellow sand dipped, in one locality, at an angle of forty-five degrees to the east-south-east, and in the other at a much higher inclination in the opposite direction. These facts would be of small interest, if these mixed marine and volcanic deposits, which encircle part of the base of Etna, had not been considered by a geologist of high authority as the outer margin of an erhebungs crater.*

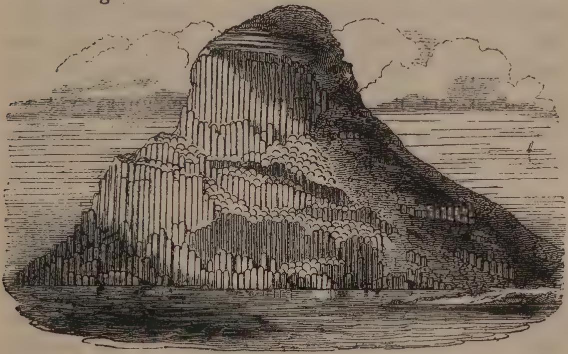
Near Catania the marine formation, consisting chiefly of volcanic tuff thinly laminated, terminates in a steep inland cliff, or escarpment, which is from six hundred to eight hundred feet in height. A low flat, composed of recent lava and volcanic sand, intervenes between the sea and the base of this escarpment, which may be well seen at Fasano. (*f*, Fig. 74.)

Eastern side of Etna—Bay of Trezza.—Proceeding northwards from Catania, we have opportunities of examining the same sub-Etnean formations laid open more distinctly in the modern sea cliffs, especially in the Bay of Trezza and in the Cyclopian islands (Dei Faraglioni), which may be regarded as the extremity of a promontory severed from the main land. Numerous are the proofs of submarine eruptions of high antiquity in this spot, where the argillaceous and sandy beds have been invaded and intersected by lava, and where those peculiar tufaceous breccias occur which result from ejections of fragmentary matter, projected from a volcanic vent. I observed many angular and hardened fragments of laminated clay (creta), in different states

* See Vol. II. p. 216.

of alteration, between La Trezza and Nizzitta, and in the hills above Aci Castello, a town on the main land contiguous to the Cyclopian isles, which could not be mistaken by one familiar with Somma and the minor cones of Ischia, for any thing but masses thrown out by volcanic explosions. From the tuffs and marls of this district I collected a great variety of marine shells, almost all of which have been identified with species now inhabiting the Mediterranean, and, for the most part, now frequent on the coast immediately adjacent.*

Fig. 77.



View of the Isle of Cyclops in the Bay of Trezza. †

* A list of sixty-five species of shells, named by M. Deshayes, which I procured from the hills called Monte Cavalaccio, Rocca di Ferro, and Rocca di Bempolere (or Borgia), was published in App. II. of 1st edit. The occurrence of shells in these and some neighbouring localities was not unknown to the naturalists of Catania; but, having been recognized by them as *recent* species, they were supposed to have been carried up from the sea-shore to fertilize the soil, and therefore disregarded. Their position is well known to many of the peasants of the country, by whom the fossils are called "roba di diluvio."

† This view of the Isle of Cyclops is from an original drawing

Some few of these fossil shells retain part of their colour, which is the same as in their living analogues.

The loftiest of the Cyclopian islets, or rather rocks, is about two hundred feet in height, the summit being formed of a mass of stratified clay (creta), the laminæ of which are occasionally subdivided by thin arenaceous layers. These strata dip to the N.W., and rest on a mass of columnar lava (see Fig. 77.), in which the tops of the pillars are weathered, and so rounded as to be often hemispherical. In some places in the adjoining and largest islet of the group, which lies to the north-eastward of that represented in the drawing (Fig. 77.), the overlying clay has been greatly altered, and hardened by the igneous rock, and occasionally contorted in the most extraordinary manner; yet the lamination has not been obliterated, but, on the contrary, rendered much more conspicuous, by the indurating process.

The annexed wood-cut (Fig. 78.) is a careful representation of a portion of the altered rock, a few feet square, where the alternating thin laminæ of sand and clay have put on the appearance which we often observe in some of the most contorted of the primary schists.

A great fissure, running from east to west, nearly divides this larger island into two parts, and lays open its internal structure. In the section thus exhibited, a dike of lava is seen, first cutting through an older mass of lava, and then penetrating the superincumbent tertiary strata. In one place, the lava ramifies and

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by my friend Captain Basil Hall, R. N., and is a correction of one given in a former edition.

Fig. 78.

Contortions in the Newer Pliocene strata in the largest of the Cyclopian Islands.

terminates in thin veins, from a few feet to a few inches in thickness (see Fig. 79.).

The arenaceous laminæ are much hardened at the point of contact, and the clays are converted into siliceous schist. In this island the altered rocks assume a honeycombed structure on their weathered surface, singularly contrasted with the smooth and even outline which the same beds present in their usual soft and yielding state.

The pores of the lava are sometimes coated, or en-

Fig. 79.

Newer Pliocene strata invaded by lava, Isle of Cyclops (horizontal section).

a. Lava. *b.* Laminated clay and sand. *c.* The same altered.

tirely filled, with carbonate of lime, and with a zeolite resembling analcime, which has been called cyclopite. The latter mineral has also been found in small fissures traversing the altered marl, showing that the same cause which introduced the minerals into the cavities of the lava, whether we suppose sublimation or aqueous infiltration, conveyed it also into the open rents of the contiguous sedimentary strata.

Lavas of the Cyclopian Isles not currents from Etna. — The phenomena of the Bay of Trezza are very important; for it is evident that the submarine lavas were produced by eruptions on the spot, an inference which follows not only from the presence of dikes and veins, but from those tuffs above Castello d'Aci, which contain angular fragments of hardened marl, evidently

thrown up, together with the sand and scoriæ, by volcanic explosions. We may, therefore, suppose this volcanic action to have been as independent of the modern vents of Etna, as that which gave rise to the analogous formations in the Val di Noto. It is quite evident that the lavas of the Cyclopian Isles are not the lower extremities of currents which flowed down from the highest crater of Etna, or from the region where lateral eruptions are now frequent,—lavas which, after entering the sea, were afterwards upraised into their present position. It is more probable that the basalts of the Bay of Trezza, and those along the southern foot of Etna, at La Motta, Adernò, Paternò, Licodia, and other places, originated in the same sea in which the eruptions of the Val di Noto took place.

There are, however, no sections to prove that the central and oldest parts of Etna repose on similar submarine formations. The modern lavas of the volcano are continually extending their area, and covering, from time to time, a larger portion of the marine strata; but we know not where this operation commenced, so that we cannot demonstrate the posteriority of the whole cone to these Newer Pliocene strata.

We might imagine that when the volcanos of the Val di Noti were in activity, and when the eruptions of the Bay of Trezza were taking place, Etna already existed as a volcano, the upper part only of the cone projecting above the level of the waters, as in the case of Stromboli at present. By such an hypothesis, we might refer the origin of the older part of Etna to the same period as that of the sedimentary strata and volcanic rocks of the Val di Noto.

But there are no obvious grounds for inclining to

such a theory; for we must admit that a sufficient series of ages has elapsed since the limestone of the Val di Noto was deposited, to allow it to be elevated to the height of from two thousand to three thousand feet, in which case there may also have been sufficient time for the growth of a volcanic pile like Etna, since the period when the Newer Pliocene strata now seen at the base of the volcano originated.

Internal Structure of the Cone of Etna.

In the second book I merely described that part of Etna which is known to have been formed during the historical era*; an insignificant portion of the whole mass. Nearly all the remainder may be referred to the tertiary period immediately antecedent to the *recent* epoch. The great cone is, in general, of a very symmetrical form, but is broken, on its eastern side, by a deep valley, called the Val del Bove, or in the provincial dialect of the peasants, "Val di Bué," for here the herdsman

> —— "in reductâ valle *mugientium*
> Prospectat errantes greges."

Dr. Buckland was, I believe, the first English geologist who examined this valley with attention, and I am indebted to him for having described it to me, before I visited Sicily, as more worthy of attention than any single spot in that island, or perhaps in Europe.

Description of Plate VIII.—The accompanying view (Pl.VIII.) is part of a panoramic sketch which I made in November, 1828, and may assist the reader in comprehending some topographical details, to be alluded

* Vol. II. p. 164.

VIEW LOOKING UP THE VAL DEL BOVE, ETNA.

to in the sequel, although it can convey no idea of the picturesque grandeur of the scene.

The great lava-currents of 1819 and 1811 are seen pouring down from the higher parts of the valley, over-running the forests of the great plain, and rising up in the foreground on the left with a rugged surface, on which many hillocks and depressions appear, such as often characterize a lava-current immediately after its consolidation.

The small cone, No. 7., was formed in 1811, and was still smoking when I saw it in 1828. The other small volcano to the left, from which vapour is issuing, was I believe one of those formed in 1819.

The following are the names of some of the other points indicated in the sketch:—

1. Montagnuola. 2. Torre del Filosofo. 3. Highest cone. 4. Lepra. 5. Finocchio. 6. Capra. 7. Cone of 1811. 8. Cima del Asino. 9. Musara. 10. Zocolaro. 11. Rocca di Calanna.

Description of Plate IX.—The second view (Pl. IX.) represents the same valley as seen from above, or looking directly down the Val del Bove, from the summit of the principal crater formed in 1819. I am unable to point out the precise spot which this crater would occupy in the view represented in Plate VIII.; but I conceive that it would appear in the face of the great precipice, near which the smoke issuing from the cone No. 7. is made to terminate. There are many ledges of rock on the face of that precipice where eruptions have occurred.

The circular form of the Val del Bove is well shown in this view (Pl. IX.). To the right and left are the lofty precipices which form the southern and northern sides of the great valley, and are intersected by dike

projecting in the manner afterwards to be described. In the distance appears the "fertile region" of Etna, extending like a great plain along the sea coast.

The spots particularly referred to in the plate are the following :—

a. Cape Spartivento, in Italy, of which the outline is seen in the distance.

b. The promontory of Taormino, on the Sicilian coast.

c. The river Alcantra.

d. The small village of Riposto.

f. Town of Aci Reale.

g. Cyclopian Islands, or "Faraglioni," in the bay of Trezza.

h. The great harbour of Syracuse.

k. City of Catania, near which is marked the course of the lava which flowed from the Monti Rossi in 1669, and destroyed part of the city.

i. The lake of Lentini.

l. To the left of the view is the crater of 1811, which is also shown at No. 7., in Plate VIII.

m. Rock of Musara, also seen at No. 9., in Plate VIII.

e. Valley of Calanna.

The Val del Bove, represented in the above drawings, commences near the summit of Etna, and descending into the woody region is farther continued on one

Fig. 80.

Great Valley on the east side of Etna.

a. Highest cone. *b*. Montagnuola.
c. Head of Val del Bove. *d, d*. Serre del Solfizio.
e. Village of Zaffarana on the lower border of the woody region. *f*. One of the lateral cones.
g. Monti Rossi.

VIEW OF VAL DEL BOVE, ETNA, AS SEEN FROM ABOVE, OR FROM CRATER OF 1819.

side by a second and narrower valley, called the Val di Calanna. Below this another, named the Val di St. Giacomo, begins, — a long narrow ravine, which is prolonged to the neighbourhood of Zaffarana (*e*. Fig. 80.) on the confines of the fertile region. These natural incisions, into the side of the volcano, are of such depth that they expose to view a great part of the structure of the entire mass, which, in the Val del Bove, is laid open to the depth of from four thousand to five thousand feet from the summit of Etna. The geologist thus enjoys an opportunity of ascertaining how far the internal conformation of the cone corresponds with what he might have anticipated as the result of that mode of increase which has been witnessed during the historical era.

It is clear, from what was before said of the gradual manner in which the principal cone increases, partly by streams of lava and showers of volcanic ashes ejected from the summit, partly by the throwing up of minor hills and the issuing of lava-currents on the flanks of the mountain, that the whole cone must consist of a series of cones enveloping others, the regularity of each being only interrupted by the interference of the lateral volcanos.

We might, therefore, have anticipated that a section of Etna, as exposed in a ravine which should begin near the summit and extend nearly to the sea, would correspond very closely to the section of the ancient Vesuvius, commencing with the escarpment of Somma, and ending with the Fossa Grande; but with this difference, that where the ravine intersects the woody region of Etna, indications must appear of changes brought about by lateral eruptions. Now the section, which can be traced from the head of the Val del Bove

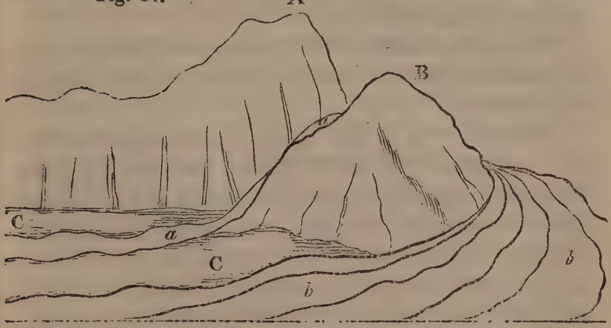
to the inferior borders of the woody region, fully answers such expectations. We find, almost every where, a series of layers of tuff and breccia interstratified with lavas, which slope gently to the sea, at an angle of from twenty to thirty degrees; and as we rise to the parallel of the zone of lateral eruptions, and still more as we approach the summit, we discover indications of disturbances, occasioned by the passage of lava from below, and the successive inhumation of lateral cones.

Val di Calanna.—On leaving Zaffarana, on the borders of the fertile region, we enter the ravine-like valley of St. Giacomo, and see on the north side, or on our right as we ascend, rising ground composed of the modern lavas of Etna. On our left, a lofty cliff, wherein a regular series of beds is exhibited, composed of tuffs and lavas, descending with a gentle inclination towards the sea. In this lower part of the section there are no intersecting dikes, nor any signs of minor cones interfering with the regular slope of the alternating volcanic products. If we then pass upwards through a defile, called the "Portello di Calanna," we enter a second valley, that of Calanna, resembling the ravine before mentioned, but wider and much deeper. Here again we find, on our right, many currents of modern lava, piled one upon the other; and on our left a continuation of our former section, in a perpendicular cliff from four hundred to five hundred feet high. As this lofty wall sweeps in a curve, it has very much the appearance of the escarpment which Somma presents towards Vesuvius, and this resemblance is increased by the occurrence of two or three vertical dikes which traverse the gently-inclined volcanic beds. When I first beheld this precipice, I fancied that I had entered a lateral crater, but was soon undeceived, by

discovering that on all sides, both at the head of the valley, in the hill of Zocolaro, and at its side and lower extremity, the dip of the beds was always in the same direction, all slanting to the east, or towards the sea, instead of sloping to the north, east, and south, as would have been the case had they constituted three walls of an ancient crater.

It is not difficult to explain how the valleys of St. Giacomo and Calanna originated, when once the line of lofty precipices on the north side of them had been formed. Many lava currents flowing down successively from the higher regions of Etna, along the foot of a great escarpment of volcanic rock, have at length been turned by a promontory at the head of the valley of Calanna, which runs out at right angles to the great line of precipices. This promontory consists of the hills called Zocolaro and Calanna, and of a ridge of inferior height which connects them. (See Fig. 81.)

Fig. 81.



A. Zocolaro. B. Monte di Calanna.

C. Plain at the head of the Valley of Calanna.

a. Lava of 1819 descending the precipice and flowing through the valley.

b. Lavas of 1811 and 1819 flowing round the hill of Calanna.

The flows of melted matter have been deflected from their course by this projecting mass, just as a tidal current, after setting against a line of sea cliffs, is often thrown off into a new direction by some rocky headland.

Lava streams, it is well known, become solid externally, even while yet in motion; and their sides may be compared to two rocky walls, which are sometimes inclined at an angle of forty-five degrees. When such streams descend a considerable slope at the base of a line of precipices, and are turned from their course by a projecting rock, they move right onwards in a new direction, so as to leave a considerable space (as in the valley of Calanna) between them and the cliffs which may be continuous below the point of deflection.

It happened in 1811 and 1819, that the flows of lava overtopped the ridge intervening between the hills of Zocolaro and Calanna, so that they fell in a cascade over a lofty precipice, and began to fill up the valley (*a*, Fig. 81.).*

The narrow cavity of St. Giacomo will admit of an explanation precisely similar to that already offered for Calanna.

Val del Bove. — After passing up through the defile, called the "Rocca di Calanna," we enter a third valley of truly magnificent dimensions — the Val del Bove — a vast amphitheatre, four or five miles in diameter, surrounded by nearly vertical precipices, varying from 1000 to above 3000 feet in height, the loftiest being at the upper end, and the height gradually diminishing on both sides. The feature which first strikes the geologist as distinguishing this valley from

* This is the cascade mentioned in Vol. II. p. 75.

those before mentioned, is the prodigious multitudes of vertical dikes, which are seen in all directions traversing the volcanic beds. The circular form of this great chasm, and the occurrence of these countless dikes, amounting perhaps to several thousands in number, so forcibly recalled to my mind the phenomena of the Atrio del Cavallo, on Vesuvius, that I imagined once more that I had entered a vast crater, on a scale as far exceeding that of Somma as Etna surpasses Vesuvius in magnitude.

But having already been deceived in regard to the crescent-shaped precipice of the valley of Calanna, I began attentively to explore the different sides of the great amphitheatre, in order to satisfy myself whether the semicircular wall of the Val del Bove had ever formed the boundary of a crater, and whether the beds had the same quâquâ-versal dip which is so beautifully exhibited in the escarpment of Somma. If the supposed analogy between Somma and the Val del Bove should hold true, the tuffs and lavas, at the head of the valley, would dip to the west, those on the north side towards the north, and those on the southern side to the south. But such I did not find to be the inclination of the beds; they all dip towards the sea, or nearly east, as in the Valley of Calanna.

There are undoubtedly exceptions to this general rule, which might deceive a geologist who was strongly prepossessed with a belief that he had discovered the hollow of an ancient crater. It is evident that, wherever lateral cones are intersected in the precipices, a series of tuffs and lavas, very similar to those which enter into the structure of the great cone, will be seen dipping at a much more rapid angle.

The lavas and tuffs, which have conformed to the

sides of Etna, dip at angles of from fifteen to twenty-five degrees, while the slope of the lateral cones is from thirty-five to fifty degrees. Now, wherever we meet with sections of these buried cones in the precipices bordering the Val del Bove (and they are frequent in the cliffs called the Serre del Solfizio, and in those near the head of the valley not far from the rock of Musara), we find the beds dipping at high angles and inclined in various directions.

Scenery of the Val del Bove. — Without entering at present into any further discussions respecting the origin of the Val del Bove, I shall proceed to describe some of its most remarkable features. Let the reader picture to himself a large amphitheatre, five miles in diameter, and surrounded on three sides by precipices from 2000 to 3000 feet in height. If he has beheld that most picturesque scene in the chain of the Pyrenees, the celebrated "cirque of Gavarnie," he may form some conception of the magnificent circle of precipitous rocks which inclose, on three sides, the great plain of the Val del Bove. This plain has been deluged by repeated streams of lava; and although it appears almost level when viewed from a distance, it is, in fact, more uneven than the surface of the most tempestuous sea. Besides the minor irregularities of the lava, the valley is in one part interrupted by a ridge of rocks, two of which, Musara and Capra, are very prominent. It can hardly be said that they

——— "like giants stand
To sentinel enchanted land;"

for although, like the Trosachs in the Highlands of Scotland, they are of gigantic dimensions, and appear almost isolated as seen from many points, yet the stern

and severe grandeur of the scenery which they adorn is not such as would be selected by a poet for a vale of enchantment. The character of the scene would accord far better with Milton's picture of the infernal world; and if we imagine ourselves to behold in motion, in the darkness of the night, one of those fiery currents which have so often traversed the great valley, we may well recall

> —— "yon dreary plain, forlorn and wild,
> The seat of desolation, void of light,
> Save what the glimmering of these livid flames
> Casts pale and dreadful."

The face of the precipices already mentioned is broken in the most picturesque manner by the vertical walls of lava which traverse them. These masses usually stand out in relief, are exceedingly diversified in form, and of immense altitude. In the autumn, their black outline may often be seen relieved by clouds of fleecy vapour which settle behind them, and do not disperse until mid-day, continuing to fill the valley while the sun is shining on every other part of Sicily, and on the higher regions of Etna.

As soon as the vapours begin to rise, the changes of scene are varied in the highest degree, different rocks being unveiled and hidden by turns, and the summit of Etna often breaking through the clouds for a moment with its dazzling snows, and being then as suddenly withdrawn from the view.

An unusual silence prevails; for there are no torrents dashing from the rocks, nor any movement of running water in this valley, such as may almost invariably be heard in mountainous regions. Every drop of water that falls from the heavens, or flows from the melting ice and snow, is instantly absorbed by the porous lava;

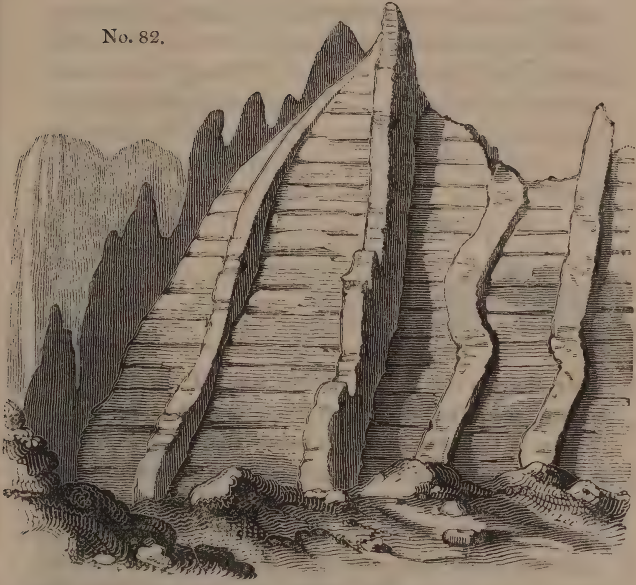
and such is the dearth of springs, that the herdsman is compelled to supply his flocks, during the hot season, from stores of snow laid up in hollows of the mountain during winter.

The strips of green herbage and forest land, which have here and there escaped the buring lavas, serve, by contrast, to heighten the desolation of the scene. When I visited the valley, nine years after the eruption of 1819, I saw hundreds of trees, or rather the white skeletons of trees, on the borders of the black lava, the trunks and branches being all leafless, and deprived of their bark by the scorching heat emitted from the melted rock; an image recalling those beautiful lines: —

> ——— "As when heaven's fire
> Hath scath'd the forest oaks, or mountain pines,
> With singed top their stately growth, though bare,
> Stands on the blasted heath."

Form, composition, and origin of the dikes. — But without indulging the imagination any longer in descriptions of scenery, I may observe, that the dikes before mentioned form unquestionably the most interesting geological phenomenon in the Val del Bove. Some of these are composed of trachyte, others of compact blue basalt with olivine. They vary in breadth from two to twenty feet and upwards, and usually project from the face of the cliffs, as represented in the annexed drawing (Fig. 82.). They consist of harder materials than the strata which they traverse, and therefore waste away less rapidly under the influence of that repeated congelation and thawing to which the rocks in this zone of Etna are exposed. The dikes are, for the most part, vertical, but sometimes they run in a tortuous course through the tuffs and

No. 82.



Dikes at the base of the Serre de Solfizio, Etna.

breccias, as represented in Fig. 83. In the escarpment of Somma, where similar walls of lava cut through alternating beds of sand and scoriæ, a coating of coal-black rock, approaching in its nature and appearance to pitch-stone, is seen at the contact of the dike with the intersected beds. I did not observe such parting layers at the junction of the Etnean dikes which I examined, but they may perhaps be discoverable.

The geographical position of these dikes is most interesting, as they are very numerous near the head of the Val del Bove, where the cones of 1811 and 1819

Fig. 83.

Veins of Lava. *Punto di Guimento.*

were thrown up, as also in that zone of the mountain where lateral eruptions are frequent; whereas, in the Valley of Calanna, which is below that parallel, and in a region where lateral eruptions are extremely rare, scarcely any dikes are seen, and none whatever still lower in the Valley of St. Giacomo. This is precisely what we might have expected, if we consider the vertical fissures now filled with rock to have been the feeders of lateral cones, or, in other words, the channels which gave passage to the lava currents and scoriæ that have issued from vents in the forest zone. There may be lateral cones in the parallel of the Valley of Calanna in other parts of Etna, because the line of lateral eruptions is not everywhere at the same height above the sea; but in the section above alluded to there appeared to me an obvious connexion between the frequency of dikes and of lateral eruptions.

Some fissures may have been filled from above, but I did not see any which, by terminating downwards, gave proof of such an origin. Almost all the isolated masses in the Val del Bove, such as Capra, Musara,

and others, are traversed by dikes, and may, perhaps, have partly owed their preservation to that circumstance, if at least the action of occasional floods has been one of the destroying causes in the Val del Bove; for there is nothing which affords so much protection to a mass of strata against the undermining action of running water, as a perpendicular dike of hard rock.

In the accompanying drawing (Fig. 84.) the flowing of the lavas of 1811 and 1819, between the rocks

Fig. 84.

View of the rocks Finochio, Capra, and Musara, Val del Bove.

Finochio, Capra, and Musara, is represented. The height of the two last-mentioned isolated masses has been much diminished by the elevation of their base, caused by these currents. They may, perhaps, be the remnants of cones which existed before the Val del Bove was formed, and may hereafter be once more buried by the lavas that are now accumulating in the valley.

From no point of view are the dikes more conspicuous than from the summit of the highest cone of Etna; a view of some of them are given in the annexed drawing (Fig. 85.).

Fig. 85.

View from the summit of Etna into the Val del Bove.

The small cone and crater immediately below were among those formed during the eruptions of 1810 *and* 1811. *

* This drawing is part of a panoramic sketch which I made from the summit of the cone, December 1. 1828, when every part of Etna was free from clouds except the Val del Bove.

Lavas and breccias. — In regard to the volcanic masses which are intersected by dikes in the Val del Bove, they consist, in great part, of greystone lavas, of an intermediate character between basalt and trachyte, and partly of the trachytic varieties of lava. Beds of scoriæ and sand, also, are very numerous, alternating with breccias formed of angular blocks of igneous rock. It is possible that some of the breccias may be referred to aqueous causes, as we have before seen that great floods do occasionally sweep down the flanks of Etna when eruptions take place in winter, and when the snows are melted by lava.

Many of the angular fragments may have been thrown out by volcanic explosions, which, falling on the hardened surface of moving lava currents, may have been carried to a considerable distance. It may also happen, that when lava advances very slowly, in the manner of the flow of 1819, described in the second volume*, the angular masses resulting from the frequent breaking of the mass, as it rolls over upon itself, may produce these breccias. It is at least certain, that the upper portion of the lava currents of 1811 and 1819 now consist of angular masses to the depth of many yards.

D'Aubuisson has compared the surface of one of the ancient lavas of Auvergne to that of a river suddenly frozen over by the stoppage of immense fragments of drift-ice, a description perfectly applicable to these modern Etnean flows.

* P. 175.

CHAPTER VIII.

NEWER PLIOCENE FORMATIONS — ETNA, *continued.*

Speculations on the origin of the Val del Bove on Etna — Subsidences — Antiquity of the cone of Etna — Mode of computing the age of volcanos — Their growth analogous to that of exogenous trees (p. 450.) — Period required for the production of the lateral cones of Etna — Whether signs of Diluvial Waves are observable on Etna.

Origin of the Val del Bove.

Before concluding my observations on the cone of Etna, the structure of which has been considered in the last chapter, I desire to call the reader's attention to several questions:—first, in regard to the probable origin of the great valley already described; secondly, whether any estimate can be made of the length of the period required for the accumulation of the great cone; and, thirdly, whether there are any signs on the surface of the older part of the mountain, of those devastating waves which, according to the theories of some geologists, have swept again and again over our continents.

I explained in the last chapter my reasons for not assenting to the opinion, that the great cavity on the eastern side of Etna was the hollow of a vast crater, from which the volcanic masses of the surrounding walls were produced. On the other hand, it seems impossible to ascribe the valley to the action of run-

ning water alone; for if it had been excavated exclusively by that power, its depth would have increased in the descent; whereas, on the contrary, the precipices are most lofty at the upper extremity, and diminish gradually on approaching the lower region of the volcano.

The structure of the surrounding walls is such as we should expect to see exhibited on any other side of Etna, if a cavity of equal depth should be caused, whether by subsidence, or by the blowing up of part of the flanks of the volcano, or by either of these causes co-operating with the removing action of running water.

Dr. Daubeny informs me, that during the eruption of Vesuvius in 1834, the mountain, and all the adjacent country was violently shaken on the night of August 24. At the same time, two small conical hillocks of volcanic matter which existed in the great crater disappeared. They do not seem to have been ejected, or blown into the air, but to have been actually swallowed up in some internal cavity.

It is recorded, as was stated in the history of earthquakes, that in the year 1772 a great subsidence took place on Papandayang, the largest volcano in the island of Java, an extent of ground, *fifteen miles in length and six in breadth*, covered by no less than forty villages, was engulphed, and the cone lost 4000 feet of its height.*

Now we might imagine a similar event, or a series of subsidences to have formerly occurred on the eastern side of Etna, although such catastrophes have not been witnessed in modern times, or only on a very

* Vol. II. p. 293.

trifling scale. A narrow ravine, about a mile long, twenty feet wide, and from twenty to thirty-six in depth, has been formed, within the historical era, on the flanks of the volcano, near the town of Mascalucia; and a small circular tract, called the Cisterna, near the summit, sank down in the year 1792 to the depth of about forty feet, and left on all sides of the chasm a vertical section of the beds, exactly resembling those which are seen in the precipices of the Val del Bove. At some remote periods, therefore, we might suppose more extensive portions of the mountain to have fallen in during great earthquakes.

But some geologists will, perhaps, incline to the opinion, that the removed mass was blown up by paroxysmal explosions, such as that which in the year 79 destroyed the ancient cone of Vesuvius, and gave rise to the escarpment of Somma. The Val del Bove, it will be remembered, lies within the zone of lateral eruptions; so that a repetition of volcanic explosions might have taken place, after which the action of running water may have contributed powerfully to degrade the rocks, and to transport the materials to the sea. I have before alluded to the effects of a violent flood, which swept through the Val del Bove in the year 1755, when a fiery torrent of lava had suddenly overflowed a great depth of snow in winter.*

In the present imperfect state of our knowledge of the history of volcanos, we have some difficulty in deciding on the relative probability of these hypotheses; but if we embrace the theory of explosions from below, the cavity would still by no means accord with the theory of the so-called "elevation craters."

* Vol. II. p. 176.

Antiquity of the Cone of Etna.

It was before remarked, that confined notions in regard to the quantity of past time have tended, more than any other prepossessions, to retard the progress of sound theoretical views in Geology *; the inadequacy of our conceptions of the earth's antiquity having cramped the freedom of our speculations in this science, very much in the same way as a belief in the existence of a vaulted firmament once retarded the progress of astronomy. It was not until Descartes assumed the indefinite extent of the celestial spaces, and removed the supposed boundaries of the universe, that just opinions began to be entertained of the relative distances of the heavenly bodies; and until we habituate ourselves to contemplate the possibility of an indefinite lapse of ages having been comprised within each of the more modern periods of the earth's history, we shall be in danger of forming most erroneous and partial views in Geology.

Mode of computing the age of volcanos.—If history had bequeathed to us a faithful record of the eruptions of Etna, and a hundred other of the principal active volcanos of the globe, during the last three thousand years,—if we had an exact account of the volume of lava and matter ejected during that period, and the times of their production,—we might, perhaps, be able to form a correct estimate of the average rate of the growth of a volcanic cone. For we might obtain a mean result from the comparison of the eruptions of so great a number of vents, however irregular might be the development of the igneous action in any one of them, if contemplated singly during a brief period.

* Vol. I. p. 111.

It would be necessary to balance protracted periods of inaction against the occasional outburst of paroxysmal explosions. Sometimes we should have evidence of a repose of seventeen centuries, like that which was interposed in Ischia, between the end of the fourth century, B. C., and the beginning of the fourteenth century of our era.* Occasionally a tremendous eruption, like that of Jorullo, would be recorded, giving rise, at once, to a considerable mountain.

If we desire to approximate to the age of a cone such as Etna, we ought first to obtain some data in regard to the thickness of matter which has been added during the historical era, and then endeavour to estimate the time required for the accumulation of such alternating lavas and beds of sand and scoriæ as are superimposed upon each other in the Val del Bove; afterwards we should try to deduce, from observations on other volcanos, the more or less rapid increase of burning mountains in all the different stages of their growth.

Mode of increase of volcanos analogous to that of exogenous trees. — There is a considerable analogy between the mode of increase of a volcanic cone and that of trees of *exogenous* growth. These trees augment, both in height and diameter, by the successive application externally of cone upon cone of new ligneous matter; so that if we make a transverse section near the base of the trunk, we intersect a much greater number of layers than nearer to the summit. When branches occasionally shoot out from the trunk they first pierce the bark; and then, after growing to a certain size, if they chance to be broken off, they may

* See Vol. II. p. 123.

become inclosed in the body of the tree, as it augments in size, forming knots in the wood, which are themselves composed of layers of ligneous matter, cone within cone.

In like manner, a volcanic mountain, as we have seen, consists of a succession of conical masses enveloping others, while lateral cones, having a similar internal structure, often project, in the first instance, like branches from the surface of the main cone, and then becoming buried again, are hidden like the knots of a tree.

We can ascertain the age of an oak or pine, by counting the number of concentric rings of annual growth, seen in a transverse section near the base, so that we may know the date at which the seedling began to vegetate. The Baobab-tree of Senegal (*Adansonia digitata*) is supposed to exceed almost any other in longevity; Adanson inferred that one which he measured, and found to be thirty feet in diameter, had attained the age of 5150 years. Having made an incision to a certain depth, he first counted three hundred rings of annual growth, and observed what thickness the tree had gained in that period. The average rate of growth of younger trees, of the same species, was then ascertained, and the calculation made according to a supposed mean rate of increase. De Candolle considers it not improbable, that the celebrated Taxodium of Chapultepec, in Mexico (*Cupressus disticha*, Linn.), which is 117 feet in circumference, may be still more aged.*

It is, however, impossible, until more data are col-

* On the Longevity of Trees, Bibliot. Univ., May, 1831.

lected respecting the average intensity of the volcanic action, to make any thing like an approximation to the age of a cone like Etna; because, in this case, the successive envelopes of lava and scoriæ are not continuous, like the layers of wood in a tree, and afford us no definite measure of time. Each conical envelope is made up of a great number of distinct lava currents and showers of sand and scoriæ, differing in quantity, and which may have been accumulated in unequal periods of time. Yet we cannot fail to form the most exalted conception of the antiquity of this mountain, when we consider that its base is about ninety miles in circumference; so that it would require ninety flows of lava, each a mile in breadth at their termination, to raise the present foot of the volcano as much as the average height of one lava current.

There are no records within the historical era which lead to the opinion, that the altitude of Etna has materially varied within the last two thousand years. Of the eighty most conspicuous minor cones which adorn its flanks, only one of the largest, Monti Rossi, has been produced within the times of authentic history. Even this hill, thrown up in the year 1669, although 450 feet in height, only ranks as a cone of second magnitude. Monte Minardo, near Bronte, rises, even now, to the height of 750 feet, although its base has been elevated by more modern lavas and ejections. The dimensions of these larger cones appear to bear testimony to *paroxysms* of volcanic activity, after which we may conclude, from analogy, that the fires of Etna remained dormant for many years — since nearly a century of rest has sometimes followed a violent eruption in the historical era. It must also be remembered,

that of the small number of eruptions which occur in a century, one only is estimated to issue from the summit of Etna for every two that proceed from the sides. Nor do all the lateral eruptions give rise to such cones as would be reckoned amongst the smallest of the eighty hills above enumerated; some of them produce merely insignificant monticules, which are soon afterwards buried by showers of ashes.

How many years then must we not suppose to have been expended in the formation of the eighty cones? It is difficult to imagine that a fourth part of them have originated during the last thirty centuries. But if we conjecture the whole of them to have been formed in twelve thousand years, how inconsiderable an era would this portion of time constitute in the history of the volcano! If we could strip off from Etna all the lateral monticules now visible, together with the lavas and scoriæ that have been poured out from them, and from the highest crater, during the period of their growth, the diminution of the entire mass would be extremely slight! Etna might lose, perhaps, several miles in diameter at its base, and some hundreds of feet in elevation; but it would still be the loftiest of Sicilian mountains, studded with other cones, which would be recalled, as it were, into existence by the removal of the rocks under which they are now buried.

There seems nothing in the deep sections of the Val del Bove to indicate that the lava currents of remote periods were greater in volume than those of modern times; and there are abundant proofs that the countless beds of solid rock and scoriæ were accumulated, as now, in succession. On the grounds, therefore, already explained, we must infer that a mass,

eight thousand or nine thousand feet in thickness, must have required an immense series of ages anterior to our historical periods, for its growth; yet the whole must be regarded as the product of a modern portion of the Newer Pliocene epoch. Such, at least, is the conclusion that seems to follow from the geological data already detailed, which show that the oldest parts of the mountain, if not of posterior date to the marine strata around its base, were at least of coeval origin.

Whether signs of Diluvial Waves are observable on Etna. — Some geologists contend, that the sudden elevation of large continents from beneath the waters of the sea have again and again produced waves which have swept over vast regions of the earth, and left enormous rolled blocks strewed upon the surface.* That there are signs of local floods of extreme violence, on various parts of the surface of the dry land, is incontrovertible, and I have endeavoured to point out causes which must for ever continue to give rise to such phenomena; but such appearances afford no geological proof of a general cataclysm. It is clear that no devastating wave has passed over the forest zone of Etna, since any of the lateral cones before mentioned were thrown up; for none of these heaps of loose sand and scoriæ could have resisted for a moment the denuding action of a violent flood.

To some, perhaps, it may appear that hills of such incoherent materials cannot be of very great antiquity, because the mere action of the atmosphere must, in the course of several thousand years, have obliterated their original forms. But there is no weight in this

* Sedgwick, Anniv. Address to the Geol. Soc., p. 35. Feb. 1831.

objection; for the older hills are covered with trees and herbage, which protect them from waste; and in regard to the newer ones, such is the porosity of their component materials, that the rain which falls upon them is instantly absorbed, and, for the same reason that the rivers on Etna have a subterranean course, there are none descending the sides of the minor cones.

No sensible alteration has been observed in the form of these cones since the earliest periods of which there are memorials; and there seems no reason for anticipating that in the course of the next ten thousand or twenty thousand years they will undergo any great alteration in their appearance, unless they should be shattered by earthquakes or covered by volcanic ejections.

I shall hereafter point out, that in other parts of Europe, similar loose cones of scoriæ, probably of higher antiquity than the whole mass of Etna, stand uninjured, at inferior elevations above the level of the sea.

CHAPTER IX.

NEWER PLIOCENE FORMATIONS OF SICILY.

Growth of submarine formations gradual — Their rise above the level of the sea — Their present position proves modifications of the earth's crust at great depths, during the Newer Pliocene period — Alterations of the surface of Sicily during and since its emergence — Forms of the Sicilian valleys — Sea cliffs — Proofs of successive elevation (p. 8.) — Valleys in the Newer Pliocene districts correspond in form to those of other regions — Migrations of animals and plants since the emergence of the newer Pliocene strata — Some species older than the stations they inhabit — Recapitulation.

HAVING in the last two chapters described the tertiary formations of the Val di Noto and Valdemone, both igneous and aqueous, I shall now proceed more fully to consider their origin, and the manner in which they may be supposed to have assumed their present position. The consideration of this subject may be naturally divided into three parts: first, we may inquire in what manner the submarine formations were accumulated beneath the waters; secondly, whether they emerged slowly or suddenly, and to what modifications in the earth's crust, at considerable depths below the

surface, their rise may be attributed; thirdly, the mutations which the surface and its inhabitants have undergone during and since the period of emergence.

Growth of submarine formations.—First, then, we are to inquire in what manner the subaqueous masses, whether volcanic or sedimentary, may have been formed. On this subject a few observations will suffice; for by reference to the two last books, the reader will learn how a single stratum, whether of sand, clay, or limestone, may be thrown down at the bottom of the sea, and how shells and other organic remains may become imbedded in it. He will also understand how one sheet of lava, or one bed of scoriæ and volcanic sand, may be spread out over a wide area, and how, at a subsequent period, a second bed of sand, clay, or limestone, or a second lava stream, may be superimposed, so that in the lapse of ages a mountain mass shall be produced.

It is enough that we should behold a single course of bricks or stones laid by the mason upon another, in order to comprehend how a massive edifice, such as the Coliseum at Rome, was erected; and we can have no difficulty in conceiving that a sea, three hundred or four hundred fathoms deep, might be filled up by sediment and lava, provided we admit an indefinite lapse of ages for the accumulation of the materials.

The sedimentary and volcanic masses of the newer Pliocene era, which, in the Val di Noto, attain the thickness of two thousand feet, are subdivided into a vast number of strata and lava streams, each of which were originally formed on the subaqueous surface, just as the tuffs and lavas, whereof sections are laid open in the Val del Bove, were each in their turn external additions to the Etnean cone.

It is also clear, that before any part of the mass of

submarine origin began to rise above the waters, the uppermost stratum of the whole must have been deposited; so that if the date of the origin of these masses be comparatively recent, still more so is the period of their rise above the level of the sea.

Subaqueous formations, how raised.—In what manner, then, and by what agency, did this rise of the subaqueous formations take place? We have seen that a vast area in Scandinavia has been slowly rising for centuries above its former level. We have also seen that in the year 1819, a tract of country in Cutch, more than fifty miles long and sixteen broad, was permanently upraised to the height of ten feet above its former position, and the earthquake which accompanied this wonderful variation of level is reported to have terminated by a volcanic eruption at Bhooj. It also appeared that when the Monte Nuovo was thrown up, in the year 1538, a large fissure approached the small town of Tripergola, emitting a vivid light, and throwing out ignited sand and scoriæ.* At length this opening reached a shallow part of the sea close to the shore, and then widened into a large chasm, out of which were discharged blocks of lava, pumice, and ashes. But no current of melted matter flowed from the orifice, although it is perfectly evident that lava existed below in a fluid state, since so many portions of it were cast up in the form of scoriæ into the air. It will be remembered that the coast near Puzzuoli rose, at that time, to the height of more than twenty feet above its former level, and that it has remained permanently upheaved to this day.†

On a review of the whole phenomena, it appears not improbable that the elevated country was forced up-

* Vol. II. p. 124. † Vol. II. p. 323.

wards by lava which did not escape, but which, after causing violent earthquakes, during several preceding months, produced at length a fissure from whence it discharged gaseous fluids, together with sand and scoriæ. The intruded mass then cooled down at a certain distance below the uplifted surface, and constituted a solid and permanent foundation.

If an habitual vent had previously existed near Puzzuoli, such as we may suppose to remain always open in the principal ducts of Vesuvius or Etna, the lava might, perhaps, have flowed over upon the surface, instead of heaving upwards the superficial strata. In that case there might have been the same conversion of sea into land, the only difference being, that the lava would have been uppermost, instead of the tufaceous strata containing shells, now seen in the plain of La Starza, and on the site of the Temple of Serapis.

But when we remember that the tertiary strata of the Val di Noto have attained the height of from fifty to two thousand feet, and in the central parts of Sicily, as at Castrogiovanni, an elevation of about three thousand feet above the level of the sea, are we prepared to suppose a solid support of igneous rock, equal in volume to the upraised tract, to have been generated below since the Newer Pliocene strata were formed? In reply to this question I may remark, that the entire mass of Iceland is said to be volcanic, an island 260 miles long by 200 in breadth, and which rises, in some spots, to the height of 6000 feet. Had the melted matter in this case been prevented from reaching the surface by the weight and tenacity of superincumbent rocks, it might, perhaps, have heaved up a district three times as extensive as Sicily. But whether we adopt this or any other hypothesis as the cause of elevation—whether we introduce the evolution

of gases, the liquefaction of rocks, or in cases like that of Sweden, their slow and gradual expansion by heat, on whatever mode of operation we speculate, it is still impossible to escape from the conclusion, that some very extraordinary change has taken place in part of the earth's crust, immediately underneath Sicily, since the Mediterranean was inhabited by the existing species of testacea. We must surely admit that the permanent upheaving of a country two or three thousand square miles in area, to an additional height of several hundred yards, implies either the intrusion of new mineral matter into the fundamental rocks, or some great modification in their character.

It would be superfluous to repeat here what has been said of the probable causes of volcanic agency, operating at considerable depths, or what has been called by some geologists *plutonic action.** But it is important to reflect, that the position of the Newer Pliocene strata, in Sicily and elsewhere, indicates that this action has been developed on a great scale since the recent species of testacea abounded. The formation of a cone, such as Etna, or of the sedimentary and volcanic rocks of the Val di Noto, are superficial mutations which are perfectly insignificant in a geological point of view, when compared with the contemporaneous changes above alluded to which must have been going on *out of sight.* The result of these operations may one day be exposed to view; but a great lapse of time will probably be required before masses formed or altered at great depths can be brought up to the surface.

> Quicquid sub terrâ est, in apricum proferet ætas
> Defodiet condetque nitentia.

* See book ii. chaps. xviii. and xix.

The deposits of our own period may sink down, and be hidden in the depths of the earth, when the plutonic formations of the Newer Pliocene era shall have become visible; and it may then be impossible to ascertain, by geological evidence, the relative date of rocks formed in the subterranean regions during the Newer Pliocene ages, and to prove that they were produced at precisely the same time with the limestone and argillaceous strata of the Val di Noto.

Changes of the Surface during and since the Emergence of the Newer Pliocene Strata.

Valleys. — Geologists who are accustomed to attribute a great proportion of the inequalities of the earth's surface to the excavating power of running water during a long series of ages, will probably look for the signs of remarkable freshness in the aspect of countries so recently elevated as the parts of Sicily already described. There is, however, nothing in the external configuration of that country which would strike the eye of the most practised observer, as peculiar and distinct in character from any other districts in Europe which are of much higher antiquity. The general outline of the hills and valleys would accord perfectly well with what may often be observed in regard to other regions of equal altitude above the level of the sea.

It is true that, towards the central parts of the island, where the argillaceous deposits are of great thickness, as around Castrogiovanni, Caltanisetta, and Piazza, the torrents are observed annually to deepen the ravines in which they flow; and the traveller occasionally finds that the narrow mule path, instead of winding round the head of a ravine, terminates abruptly

in a deep trench which has been hollowed out, during the preceding winter, through soft clay. But throughout a great part of Italy, where the marls and sands of the Subapennine hills are elevated to considerable heights, the same rapid degradation is often perceived.

In the limestone districts of the Val di Noto, the strata are for the most part nearly horizontal, and on each side of the valley form a succession of ledges or small terraces, instead of descending in a gradual slope towards the river-plain in the manner of the argillaceous formations. When there is a bend in the valley, the exact appearance of an amphitheatre with a range of marble seats is produced. A good example of this configuration occurs near the town of Melilli, in the Val di Noto, as seen in the annexed view (Fig. 86.) In the south of the island, as near Spaccaforno,

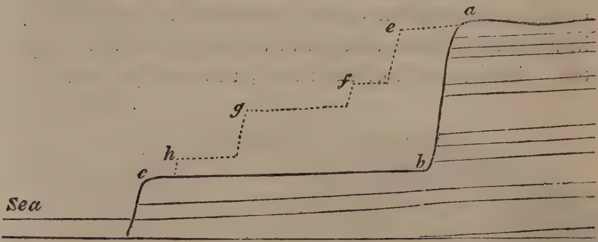
Fig. 86.

Valley called Gozzo degli Martiri, below Melilli.

Scicli, and Modica, precipitous rocks of white limestone, ascending to the height of five hundred feet,

have been carved out into the same form. It is not easy to account for this phenomenon; but it may perhaps be due to the action of the sea during the rise of the land, for every portion of the cliffs bordering these valleys may in its turn have been washed by the waves. We find evident signs of two periods of elevation in a long range of inland cliff on the east side of the Val di Noto, both to the north of Syracuse, beyond Melilli, and to the south beyond the town of Noto. The great limestone formation terminates suddenly towards the sea in a lofty precipice, *a*, *b*, which varies in height from 500 to 700 feet, and may remind the

Fig. 87.



English geologist of some of the most perpendicular escarpments of our chalk and oolite. Between the base of the precipice *a*, *b*, and the sea is an inferior platform *c*, *b*, consisting of similar white limestone. All the strata dip towards the sea, but are usually inclined at a very slight angle; they are seen to extend uninterruptedly from the base of the escarpment into the platform, showing distinctly that the lofty cliff was not produced by a fault or vertical shift of the beds, but by the removal of a considerable mass of rock. Hence we may conclude that the sea, which is now

undermining the cliffs of the Sicilian coast, reached at some former period the base of the precipice *a*, *b*, at which time the surface of the terrace *c*, *b*, must have been covered by the Mediterranean. Here, then, we have proofs of at least two elevations, but there may have been many others.

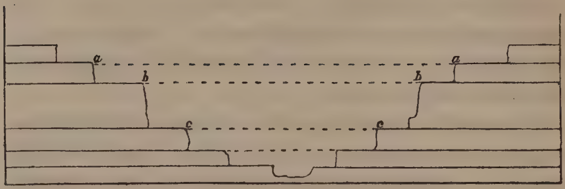
Suppose, for example, that a series of escarpments, *e*, *f*, *g*, *h*, once existed, and that during a long interval, free from subterranean movements, the sea advances along the line *c*, *b*, all preceding cliffs must have been swept away one after the other, and reduced to the single precipice *a*, *b*.

I have stated, in the second volume, that the waves washed the base of the inland cliff of Puzzuoli, in the Bay of Baiæ, within the historical era, and that the retiring of the sea was caused, in the sixteenth century, by an upheaving of the land to the height of twenty feet above its original level.* At that period, a terrace twenty feet high in some parts was laid dry between the sea and the cliff; but the Mediterranean is hastening by its encroachments to resume its former position, and the terrace will be eventually destroyed, and every trace of the *successive* rise of the land obliterated.

In those valleys where the opposite sides form a great flight of steps from top to bottom we may suppose the sea to have stood successively at many different levels, as at *a a*, *b b*, *c c*, in the annexed figure (88.); and if the separate movements of elevation followed each other more rapidly as the land continued to rise, then would the gradual contraction of the valley in its lower parts be explained, for the intervals of time

* P. 324.

Fig. 88.



would be shortened in which each successive excavation was accomplished. This hypothesis by no means requires that terraces and small precipices should be always formed on the opposite sides of each valley at corresponding levels; for the amount and depth of erosion by the waves would be determined by the set of the winds and currents, the varying hardness of the strata, the form of the ancient coast, and a variety of other accidents.

The line of some of the valleys near Lentini has evidently been determined mainly by the direction of the elevatory force, as there is an anticlinal dip in the strata on either side of the valley. The same is, probably, the case in regard to the great valley of the Anapo, which terminates at Syracuse.

I have been led into these observations, in order to show that the principal features in the physical geography of Sicily are by no means inconsistent with the hypothesis of the successive elevation of the country by the intermittent action of ordinary earthquakes. On the other hand, the magnitude of the valleys, and their correspondence in form with those of other parts of the globe, seem to lend countenance to the theory of the slow and gradual rise of subaqueous strata.

The excavation of valleys, as was before remarked, must always proceed with the greatest rapidity when the levels of a country are undergoing alteration from time to time by earthquakes; and it is principally when a country is rising or sinking by successive movements, that the power of aqueous causes, such as tides, currents, rivers, and land-floods, is exerted with the fullest energy.*

In order, therefore, to explain the present appearance of the surface, we must first go back to the time when the Sicilian formations were mere shoals at the bottom of the sea, in which the currents may have scooped out channels here and there. We must next suppose these shoals to have become small islands, of which the cliffs were thrown down from time to time, as were those of Gian Greco, in Calabria, during the earthquake of 1783. The waves and currents would have continued their denuding action during the emergence of these islands, until at length, when the intervening channels were laid dry, and rivers began to flow, the deepening and widening of the valleys by rivers and land-floods would proceed in the same manner as in modern times in Calabria.†

Before a tract could be upraised to the height of several thousand feet above the level of the sea, the joint operation of running water and subterranean movements must greatly modify its physical geography; but when the action of the volcanic forces has been suspended, when a period of tranquillity succeeds, and the levels of the land remain fixed and stationary, the erosive power of water must soon be reduced to a state of comparative equilibrium. For

* Vol. II. p. 281. † Ibid.

this reason, a country that has been raised at a very remote period to a considerable height above the level of the sea may present nearly the same external configuration as one that has been more recently uplifted to the same height.

Migration of animals and plants. — The changes above described, which have been brought about by igneous and aqueous agency, cannot fail to strike the imagination, when we consider how recent in the calendar of nature is the epoch to which they are referred. But if we turn our thoughts to the organic world, we shall feel, perhaps, no less surprise at the great vicissitude which it has undergone during the same period.

We have seen that a large portion of Sicily has been converted from sea to land since the Mediterranean was peopled with the living species of testacea and zoophytes. The newly emerged surface, therefore, must, during this modern zoological epoch, have been inhabited for the first time by the terrestrial plants and animals which now abound in Sicily. It is fair to infer that the existing terrestrial species are, for the most part, of as high antiquity as the marine; and if this be the case, a large proportion of the plants and animals, now found in the tertiary districts in Sicily, must have inhabited the earth before the Newer Pliocene strata were raised above the waters. The plants of the flora of Sicily are common, almost without exception, to Italy or Africa, or some of the countries surrounding the Mediterranean; so that we may suppose the greater part of them to have migrated from pre-existing lands, just as the plants and animals of the Phlegræan fields have colonized Monte

Nuovo, since that mountain was thrown up in the sixteenth century.*

We are brought, therefore, to admit the curious result, that the flora and fauna of the Val di Noto, and some other mountainous regions of Sicily, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters. Such conclusions throw a new light on the adaptation of the attributes and migratory habits of animals and plants, to the changes which are unceasingly in progress in the inanimate world. It is clear that the duration of species is so great, that they are destined to outlive many important revolutions in the physical geography of the earth; and hence those innumerable contrivances for enabling the subjects of the animal and vegetable creation to extend their range, the inhabitants of the land being often carried across the ocean, and the aquatic tribes over great continental spaces.† It is obviously expedient that the terrestrial and fluviatile species should not only be fitted for the rivers, valleys, plains, and mountains which exist at the era of their creation, but for others that are destined to be formed before the species shall become extinct; and, in like manner, the marine species are not only made for the deep and shallow regions of the ocean existing at the time when they are called into being, but for tracts that may be submerged or

* Professor Viviani of Genoa informed me, that, considering the great extent of Sicily, it was remarkable that its flora produced scarcely any, *if any peculiar indigenous* species; whereas there are several in Corsica, and some other Mediterranean islands.

† See book iii. chaps. v. vi. and vii.

variously altered in depth during the time that is allotted for their continuance on the globe.

Recapitulation. — I may now briefly recapitulate some of the most striking results deduced from the investigation of a single district where the Newer Pliocene strata are largely developed.

In the first place, we have seen reason to infer that a stratified mass of solid limestone, attaining sometimes a thickness of eight hundred feet and upwards, has been gradually deposited at the bottom of the sea, the imbedded fossil shells and corallines being almost all of recent species; yet these fossils are frequently in the state of mere casts, so that in appearance they correspond very closely to organic remains found in limestones of very ancient date.

2dly. In some localities the limestone above mentioned alternates with volcanic rocks, such as have been formed by submarine eruptions, recurring again and again at distant intervals of time.

3dly. Argillaceous and sandy deposits have also been produced during the same period, and their accumulation has also been accompanied by submarine eruptions. Masses of mixed sedimentary and igneous origin, at least two thousand feet in thickness, can thus be shown to have accumulated since the sea was peopled with the greater number of the aquatic species now living.

4thly. These masses of submarine origin have, since their formation, been raised to the height of two thousand or three thousand feet above the level of the sea, and this elevation implies an extraordinary modification in the state of the earth's crust at some unknown depth beneath the tract so upheaved.

5thly. This modification may possibly correspond

with the effects of what is usually called "plutonic action," or the agency of volcanic and other causes at considerable depths; in which case, the Newer Pliocene plutonic rocks, formed beneath Sicily, must be of great extent.

6thly. Considerable inequalities must have been caused on the surface of the new-raised lands during the emergence of the Newer Pliocene strata, by the action of tides, currents, and rivers, combined with the disturbing and dislocating force of the elevatory movements.

7thly. There are no features in the forms of the valleys and sea-cliffs thus recently produced which indicate the sudden rise of the strata to their present altitude, while there are some proofs of distinct and partial elevations at successive periods.

8thly. We may infer that the species of terrestrial and fluviatile animals and plants which now inhabit extensive districts, formed during the Newer Pliocene era, were in existence not only before the new strata were raised, but before their materials were brought together at the bottom of the sea.

CHAPTER X.

NEWER PLIOCENE FORMATIONS — MARINE AND VOLCANIC.

Tertiary formations of Campania — Comparison of the recorded changes in this region with those commemorated by geological monuments — Dikes of Somma — Parallelism of their opposite sides (p. 21.) — Age of the volcanic and associated rocks of Campania — Organic remains — No signs of diluvial waves — Marine Newer Pliocene strata chiefly seen in countries of earthquakes (p. 31.) — Illustrations from Chili — Peru — Parallel roads of Coquimbo — West Indies (p. 36.) — East Indian archipelago — Red Sea.

Tertiary Formations of Campania.

Comparison of recorded changes with those commemorated by geological monuments.—In the second volume I traced the various changes which the volcanic region of Naples is known to have undergone during the last two thousand years; and, imperfect as are our historical records, the aggregate effect of igneous and aqueous agency, during that period, was shown to be far from insignificant. The rise of the modern cone of Vesuvius, since the year 79, was the most memorable event during those twenty centuries; but, in addition to this remarkable phenomenon, I enumerated the production of several new minor cones in Ischia, and of the Monte Nuovo, in the year 1538. The flowing also of lava currents upon the land and along the bottom of the

sea was described,—the showering down of volcanic sand, pumice, and scoriæ, in such abundance that whole cities were buried,—the filling up or shoaling of certain tracts of the sea, and the transportation of tufaceous sediment by rivers and land floods. I also explained the evidence in proof of a permanent alteration of the relative levels of the land and sea in several places, and of the same tract having, near Puzzuoli, been alternately upheaved and depressed to the amount of more than twenty feet. In connection with these convulsions, I pointed out that, on the shores of the Bay of Baiæ, there are recent tufaceous strata filled with fabricated articles, mingled with marine shells. It was also shown that the sea has been making gradual advances upon the coast, not only sweeping away the soft tuffs of the Bay of Baiæ, but excavating precipitous cliffs, where the hard Ischian and Vesuvian lavas have flowed down into the deep.

These events, it may be objected, although interesting, are the results of operations on a very inferior scale to those indicated by geological monuments. When we examine this same region, it will be said we find that the ancient cone of Vesuvius, called Somma, is larger than the modern cone, and is intersected by a greater number of dikes,—the hills of unknown antiquity, such as Astroni, the Solfatara, and Monte Barbaro, formed by separate eruptions, in different parts of the Phlegræan fields, far outnumber those of similar origin, which are recorded to have been thrown up within the historical era. In place of modern tuffs of slight thickness, and single flows of lava, we find, amongst the older formations, hills from 500 to more than 2000 feet in height, composed of an immense

series of tufaceous strata, alternating with distinct lava currents. We have evidence that in the lapse of past ages, districts, not merely a few miles square, were upraised to the height of twenty or thirty feet above their former level, but that extensive and mountainous countries were uplifted to an elevation of more than 1000 feet, and at some points more than 2000 feet, above the level of the sea.

These and similar objections are made by those who compare the modern effects of igneous and aqueous causes, not with a part but with the whole results of the same agency in antecedent ages. Thus viewed in the aggregate, the leading geological features of each district must always appear to be on a colossal scale, just as a large edifice may seem an effort of superhuman power, until we reflect on the innumerable minute parts of which it is composed, the number of the builders, and the time required to raise it. A mountain mass, so long as the imagination is occupied in contemplating the gigantic whole, must appear the work of extraordinary causes; but when the separate portions of which it is made up are carefully studied, they are seen to have been formed successively; and the dimensions of each part, considered singly, are soon recognized to be comparatively insignificant, so that it appears no longer extravagant to liken them to the recorded effects of ordinary causes.

Difference in the composition of Somma and Vesuvius.

As no traditional accounts have been handed down to us of the eruptions of the ancient Vesuvius, from the times of the earliest Greek colonists, the volcano must have been dormant for many centuries, perhaps

for thousands of years, previous to the great eruption in the reign of Titus. But it will be shown hereafter that there are sufficient grounds for presuming this mountain, and the other igneous products of Campania, to have been produced during the Newer Pliocene period.

We have seen that the ancient and modern cones of Vesuvius were each a counterpart of the other in structure*; and I may now remark that the principal point of difference consists in the greater abundance in the older cone of fragments of altered sedimentary rocks ejected during eruptions. We may easily conceive that the first explosions would act with the greatest violence, rending and shattering whatever solid masses obstructed the escape of lava and the accompanying gases, so that great heaps of ejected pieces of rock would naturally occur in the tufaceous breccias formed by the earliest eruptions. But when a passage had once been opened and an habitual vent established, the materials thrown out would consist of liquid lava, which would take the form of sand and scoriæ, or of angular fragments of such solid lavas as may have choked up the vent.

Among the fragments which abound in the tufaceous breccias of Somma, none are more common than a saccharoid dolomite, supposed to have been derived from an ordinary limestone altered by heat and volcanic vapours.

Carbonate of lime enters into the composition of so many of the simple minerals found in Somma, that M. Mitscherlich, with much probability, ascribes their

* Vol. II. p. 140.

great variety to the action of the volcanic heat on subjacent masses of limestone.

Dikes of Somma.—The dikes seen in the great escarpment which Somma presents towards the modern cone of Vesuvius are very numerous. They are for the most part vertical, and traverse at right angles the beds of lava, scoriæ, volcanic breccia, and sand, of which the ancient cone is composed. They project in relief several inches, or sometimes feet, from the face of the cliff, like the dikes of Etna already described (see Fig. 82.), being, like them, extremely compact, and less destructible than the intersected tuffs and porous lavas. In vertical extent they vary from a few yards to 500 feet, and in breadth from one to twelve feet. Many of them cut all the inclined beds in the escarpment of Somma from top to bottom, others stop short before they ascend above half way, and a few terminate at both ends, either in a point or abruptly. In mineral composition they scarcely differ from the lavas of Somma, the rock consisting of a base of leucite and augite, through which large crystals of augite and some of leucite are scattered.* Examples are not rare of one dike cutting through another, and in one instance a shift or fault is seen at the point of intersection. I observed before, when speaking of the dikes of the modern cone of Vesuvius, that they must have been produced by the filling up of open fissures by liquid lava.† In some examples, however, the rents seem to have been filled laterally.

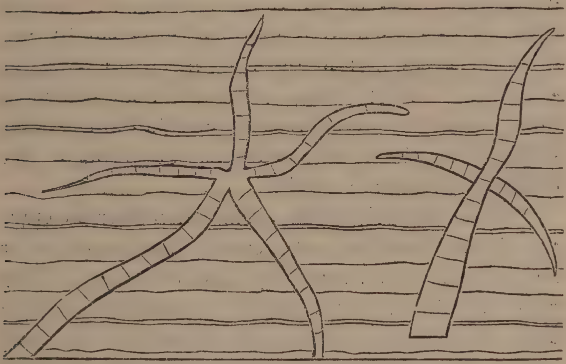
The reader will remember the description before

* Consult the valuable memoir of M. L. A. Necker, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tome ii. part i., Nov. 1822.

† Vol. II. p. 138.

given of the manner in which the plain of Jerocarne, in Calabria, was fissured by the earthquake of 1783, so that the academicians compared it to the cracks in a broken pane of glass.* If we suppose the side walls of the ancient crater of Vesuvius to have been

Fig. 89.



Dikes or veins at the Punto del Nasone on Somma.

cracked in like manner, and the lava to have entered the rents and become consolidated, we can explain the singular form of the veins figured in the accompanying wood-cut.†

Parallelism of their opposite sides. — Nothing is more remarkable than the parallelism of the opposite sides of the dikes, which usually correspond with as much regularity as the two opposite faces of a wall of masonry. This character appears at first the more inexplicable, when we consider how jagged and uneven are the rents caused by earthquakes in masses of heterogeneous composition like those composing the

* See Vol. II. p. 266. Fig. 34.

† From a drawing of M. Necker, in Mém. before cited.

cone of Somma; but M. Necker has offered an ingenious and, I think, satisfactory explanation of the phenomenon. He refers us to Sir W. Hamilton's account of an eruption of Vesuvius in the year 1779, who records the following facts:—"The lavas, when they either boiled over the crater, or broke out from the conical parts of the volcano, constantly formed channels as regular as if they had been cut by art, down the steep part of the mountain; and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so, according to the quantity of matter in motion.

"These channels, upon examination after an eruption, I have found to be in general from two to five or six feet wide, and seven or eight feet deep. They were often hid from the sight by a quantity of scoriæ that had formed a crust over them; and the lava, having been conveyed in a covered way for some yards, came out fresh again into an open channel. After an eruption I have walked in some of those subterraneous or covered galleries, which were exceedingly curious, the sides, top, and bottom, *being worn perfectly smooth and even* in most parts, by the violence of the currents of the red-hot lavas, which they had conveyed for many weeks successively."

In another place, in the same memoir, he describes the liquid and red-hot matter as being received "into a regular channel, raised upon a sort of wall of scoriæ and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct."*

Now, if the lava in these instances had not run out

* Phil. Trans., vol. lxx. 1780.

from the covered channel, in consequence of the declivity whereon it was placed—if, instead of the space being left empty, the lava had been retained within until it cooled and consolidated, it would then have constituted a small dike with parallel sides. But the walls of a vertical fissure through which lava has ascended in its way to a volcanic vent, must have been exposed to the same erosion as the four sides of the channels before adverted to. The prolonged and uniform friction of the heavy fluid, as it is forced and made to flow upwards, cannot fail to wear and smooth down the surfaces on which it rubs, and the intense heat must melt all such masses as project and obstruct the passage of the incandescent fluid.

I do not mean to assert that the sides of fissures caused by earthquakes are never smooth and parallel, but they are usually uneven, and are often seen to have been so where volcanic or *trap* dikes are as regular in shape as those of Somma. The solution, therefore, of this problem, in reference to the modern dikes, is most interesting, as being of very general application in geology.

Varieties in their texture. — Having explained the origin of the parallelism of the sides of a dike, we have next to consider the difference of its texture at the edges and in the middle. Towards the centre, observes M. Necker, the rock is larger grained, the component elements being in a far more crystalline state; while at the edge the lava is sometimes vitreous, and always finer grained. A thin parting band, approaching in its character to pitchstone, occasionally intervenes on the contact of the vertical dike and intersected beds. M. Necker mentions one of these at the place called Primo Monte, in the Atrio del Cavallo; I saw three

or four others in different parts of the great escarpment. These phenomena are in perfect harmony with the results of the experiments of Sir James Hall and Mr. Gregory Watt, which have shown that a glassy texture is the effect of sudden cooling, and that, on the contrary, a crystalline grain is produced where fused minerals are allowed to consolidate slowly and tranquilly under high pressure.

It is evident that the central portion of the lava in a fissure would, during consolidation, part with its heat more slowly than the sides, although the contrast of circumstances would not be so great as when we compare the lava at the bottom and at the surface of a current flowing in the open air. In this case the uppermost part, where it has been in contact with the atmosphere, and where refrigeration has been most rapid, is always found to consist of scoriform, vitreous, and porous lava, while at a greater depth the mass assumes a more lithoidal structure, and then becomes more and more stony as we descend, until at length we are able to recognize with a magnifying glass the simple minerals of which the rock is composed. On penetrating still deeper, we can detect the constituent parts by the naked eye, and in the Vesuvian currents distinct crystals of augite and leucite become apparent.

The same phenomenon, observes M. Necker, may readily be exhibited on a smaller scale, if we detach a piece of liquid lava from a moving current. The fragment cools instantly, and we find the surface covered with a vitreous coat, while the interior, although extremely fine grained, has a more stony appearance.

It must, however, be observed, that although the

lateral portions of the dikes are finer grained than the central, yet the vitreous parting layer before alluded to is extremely rare. This may, perhaps, be accounted for, as the above-mentioned author suggests, by the great heat which the walls of a fissure may acquire before the fluid mass begins to consolidate, in which case the lava, even at the sides, would cool very slowly. Some fissures, also, may be filled from above; and in this case the refrigeration at the sides would be more rapid than when the melted matter flowed upwards from the volcanic foci, in an intensely heated state.

The rock composing the dikes of Somma is far more compact than that of ordinary lava, for the pressure of a column of melted matter in a fissure greatly exceeds that in an ordinary stream of lava; and pressure checks the expansion of those gases which give rise to vesicles in lava.

There is a tendency in almost all the Vesuvian dikes to divide into horizontal prisms *, a phenomenon in accordance with the formation of vertical columns in horizontal beds of lava; for in both cases the divisions which give rise to the prismatic structure are at right angles to the cooling surfaces.

Minor cones of the Phlegræan Fields. — In the volcanic district of Naples there are a great number of conical hills with craters on their summits, which have evidently been produced by one or more explosions, like that which threw up the Monte Nuovo in 1538. They are composed of trachytic tuff, which is loose and incoherent, both in the hills and, to a certain depth, in the plains around their base, but which is in-

* See Fig. 89. p. 21.

durated below. It is suggested by Mr. Scrope, that this difference may be owing to the circumstance of the volcanic vents having burst out in a shallow sea, as was the case with Monte Nuovo, where there is a similar foundation of hard tuff, under a covering of loose lapilli. The subaqueous part may have become solid by an aggregative process like that which takes place in the setting of mortar, while the rest of the ejections, having accumulated on dry land when the cone was raised above the water, may have remained in a loose state.*

Age of the volcanic and associated rocks of Campania. — If we inquire into the evidence derivable from organic remains, respecting the age of the volcanic rocks of Campania, we find reason to conclude that such parts as do not belong to the Recent are referrible to the Newer Pliocene period. In the solid tuff quarried out of the hills immediately behind Naples, are found recent shells of the genera Ostrea, Cardium, Buccinum, and Patella, all referrible to species now living in the Mediterranean.† In the centre of Ischia the lofty hill called Epomeo, or San Nichola, is composed of greenish indurated tuff of a prodigious thickness, interstratified in some parts with argillaceous marl, and here and there with great streams of indurated lava. Visconti ascertained by trigonometrical measurement that this mountain was 2605 feet above the level of the sea. In mineral composition and in form, as seen from many points of view, it resembles the hill to the north of Naples on the summit of which stands the convent of Camaldoli, which is 1643 feet in height. I collected in 1828 many recent marine shells from beds

* Geol. Trans., vol. ii. part iii. p. 351. Second Series.

† Scrope, ibid.

of clay and tuff, not far from the summit of Epomeo, about 2000 feet above the level of the sea, as also at another place, about 100 feet below the first, on the southern declivity of the mountain, and others still lower, not far above the town of Moropano. At Casamicciol, and several places near the sea-shore, shells have long been observed in stratified tuff and clay. From these various points I obtained, during a short excursion in Ischia, twenty-eight species of shells, all of which, with one exception, were identified by M. Deshayes with recent species.*

It is clear, therefore, that the great mass of Epomeo was not only raised to its present height above the level of the sea, but was also *formed*, since the Mediterranean was inhabited by the existing species of testacea.

In the Ischian tuffs we find pumice, lapilli, angular fragments of trachytic lava, and other products of igneous ejections, interstratified with some deposits of clay free from any intermixture of volcanic matter. These clays might have resulted from the decomposition of felspathic lava which abounds in Ischia, the materials having been transported by rivers and marine currents, and spread over the bottom of the sea where testacea were living. All these submarine tuffs, lavas, and clays of Campania, very much resemble those around the base of Etna, and in parts of the Val di Noto before described.

External configuration of the country, how caused. — When once we have satisfied ourselves by inspection of the marine shells imbedded in tuffs at high elevations, that a mass of land like the island of Ischia has been

* See the list of these shells, Appendix II. first ed.

raised from beneath the waters of the sea to its present height, we are prepared to find signs of the denuding action of the waves impressed upon the outward form of the island, especially if we conceive the upheaving force to have acted by successive movements. Let us suppose the low contiguous island of Procida to be raised by degrees until it attains the height of Ischia; we should in that case expect the steep cliffs which now face Misenum to be carried upwards, and to become precipices near the summit of the central mountain. Such, perhaps, may have been the origin of those precipices which appear on the north and south sides of the ridge which forms the summit of Epomeo in Ischia. The northern escarpment is about 1000 feet in height, rising from the hollow called the Cavo delle Neve, above the village of Panella. The abrupt manner in which the horizontal tuffs are there cut off, in the face of the cliff, is such as the action of the sea, working on soft materials, might easily have produced, undermining and removing a great portion of the mass. A heap of shingle which lies at the base of a steep declivity on the flanks of Epomeo, between the Cavo delle Neve and Panella, may once, perhaps, have been a sea-beach, for it certainly could not have been brought to the spot by any existing torrents.

There is no difficulty in conceiving that if a large tract of the bed of the sea near Ischia should now be gradually upheaved during the continuance of volcanic agency, this newly raised land might present a counterpart to the Phlegræan Fields before described. Masses of alternating lava and tuff, the products of submarine eruptions, might on their emergence become hills and islands; the level intervening plains might afterwards appear, covered partly by the ashes

drifted and deposited by water, and partly by those which would fall after the laying dry of the tract. The last features imparted to the physical geography would be derived from such eruptions in the open air as those of Monte Nuovo and the minor cones of Ischia.

No signs of diluvial waves.— Such a conversion of a large tract of sea into land might possibly take place, while the surface of the contiguous country underwent but slight modification. No great wave was caused by the permanent rise of the coast near Puzzuoli in the year 1538, because the upheaving operation appears to have been effected by a succession of minor shocks.* A series of such movements, therefore, might produce an island like Ischia without throwing a diluvial rush of waters upon low parts of the neighbouring continent. The advocates of paroxysmal elevations may, perhaps, contend that the rise of Ischia must have been anterior to the birth of all the cones of loose scoriæ scattered over the Phlegræan Fields; for, according to them, the sudden rise of marine strata causes inundations which devastate adjoining continents. But the absence of any signs of such floods in the volcanic region of Campania does not appear to me to warrant the conclusion, either that Ischia was raised previously to the production of the volcanic cones, or that it may not have been rising during the whole period of their formation.

We learn from the study of the mutations now in progress, that one part of the earth's surface may, for an indefinite period, be the scene of continued change, while another, in the immediate vicinity, remains sta-

* See Vol. II. p. 312.

tionary. We need go no farther than our own country to illustrate this principle; for, reasoning from what has taken place in the last ten centuries, we must anticipate that in the course of the next four thousand or five thousand years, a long strip of land, skirting the line of our eastern coast, will be devoured by the ocean, while part of the interior, immediately adjacent, will remain at rest and entirely undisturbed. The analogy holds true in regions where the volcanic fires are at work; for part of the Philosopher's Tower on Etna has stood for the last two thousand years, at the height of more than nine thousand feet above the sea, between the foot of the highest cone and the edge of the precipice which overhangs the Val del Bove, whilst large tracts of the surrounding district have been the scenes of tremendous convulsions. The great cone above has more than once been destroyed, and again renewed; the earth has sunk down in the neighbouring Cisterna *; the cones of 1811 and 1819 have been thrown up, on the ledge of rock below, pouring out of their craters two copious streams of lava; the watery deluge of 1755, descending from the desert region into the Val del Bove, has rolled vast heaps of rocky fragments towards the sea; fissures, several miles in length, have opened on the flanks of Etna; towns and villages have been laid in ruins by earthquakes, or buried under lava and ashes; — yet the tower has stood, as if placed there to commemorate the stability of one part of the earth's surface, while others in immediate proximity have been subject to most wonderful vicissitudes.

In concluding what I have to say of the marine and

* See Vol. III. p. 448.

volcanic formations of the Newer Pliocene period, I may notice the highly interesting fact, that the marine strata of this era have been found at great elevations, chiefly in those countries where earthquakes have occurred during the historical ages. On the other hand, it is a still more striking fact, that there is no example of any extensive maritime district, now habitually agitated by violent earthquakes, which has not, when carefully investigated, yielded traces of marine strata, either of Recent or Newer Pliocene eras, at a considerable height above the sea.

Chili—Conception Bay.—In illustration of the above remarks, I may mention that on the western coast of South America marine deposits occur, containing precisely the same shells as are now living in the Pacific. In Chili, for example, as before stated, micaceous sand, containing the fossil remains of such species as now inhabit the Bay of Conception, are found at the height of from 1000 to 1500 feet above the level of the ocean.* It is impossible to say how much of this rise may have taken place during the *Recent* period. One earthquake appears to have raised this part of the Chilian coast, in 1750, to the height of at least twenty-five feet above its former level. If we could suppose a series of such shocks to occur, one in every century, only 6000 years would be required to uplift the coast 1500 feet. But we have no data for inferring that so great a quantity of elevation has taken place in that space of time; and although there is no evidence that the micaceous sand may not belong to the Recent period, I think it more probable that it was deposited during the Newer Pliocene period.

* Vol. II. p. 300.

Peru.—I have been informed by Mr. A. Cruckshanks, a naturalist who resided for several years in South America, that in the valley of Lima, or Rimao, where the subterranean movements have been so violent in recent times, there are indications not only of a considerable rise of the land, but of that rise having resulted from *successive* movements. Distinct lines of ancient sea-cliffs have been observed at various heights, at the base of which the hard rocks of greenstone are hollowed out into precisely those forms which they now assume between high and low water mark on the shores of the Pacific. Immediately below these water-worn lines are ancient beaches strewed with rounded blocks. One of these cliffs appears in the hill behind Baños del Pujio, about seven hundred feet above the level of the sea, and two hundred above the contiguous valley. Another occurs at Amancaes, at the height of perhaps two hundred feet above the sea; and others at intermediate elevations.

Parallel Roads of Coquimbo.—We can hardly doubt that the parallel roads of Coquimbo, in Chili, described by Captain Hall, owe their origin to similar causes. These roads, or shelves, occur in a valley six or seven miles wide, which descends from the Andes to the Pacific. Their general width is from twenty to fifty yards, but they are, at some places, half a mile broad. They are so disposed as to present exact counterparts of one another, at the same level, on opposite sides of the valley. There are three distinctly characterized sets; the upper one lies about three or four hundred feet above the level of the sea; the next twenty yards lower; and the lowest about ten yards still lower. Each resembles a shingle beach, being formed entirely of loose materials, principally water-worn rounded stones,

from the size of a nut to that of a man's head. The stones are principally granite and gneiss, with masses of schistus, whinstone, and quartz, mixed indiscriminately, and all bearing marks of having been worn by attrition under water.*

The theory proposed by Captain Hall to explain these appearances is the same as that which had been adopted to account for the analogous parallel roads of Glen Roy in Scotland.† The valley is supposed to have been a lake, the waters of which stood, originally, at the level of the highest road, until a flat beach was produced. A portion of the barrier was then broken down, which allowed the lake to discharge part of its waters into the sea, and, consequently, to fall to the second level; and so on successively till the whole embankment was washed away, and the valley left as we now see it.

As I did not feel satisfied with this explanation, I applied to my friend Captain Hall for additional details, and he immediately sent me his original manuscript notes, requesting me to make free use of them. In them I find the following interesting passages, omitted in his printed account:—"The valley is completely open towards the sea; if the roads, therefore, are the beaches of an ancient lake, it is difficult to imagine a catastrophe sufficiently violent to carry away the barrier, which should not at the same time obliterate all traces of the beaches. I find it difficult also to account for the water-worn character of all the stones, for they have the appearance of having travelled over a great distance, being well rounded and dressed. They

* Captain Hall's South America, vol. ii. p. 9.

† See Sir T. D. Lauder, Ed. Roy. Soc. Trans., vol. ix.; and Dr. Macculloch, Geol. Trans., 1st Series, vol. iv. p. 314.

are in immense quantity too, and much more than one could expect to find on the beach of any lake, and *seem more properly to belong to the ocean*."

I had entertained a strong suspicion, before reading these notes, that the beaches were formed by the waves of the Pacific, and not by the waters of a lake; in other words, that they bear testimony to the successive rise of the land, not to the repeated fall of the waters of a lake. M. Boblaye has discovered four or five distinct ranges of ancient sea-cliffs, one above the other, at various heights, in the Morea, which attest that that country has been upheaved at as many successive periods. He found inland terraces or beaches, covered with shells, at the base of precipices worn like the modern sea-cliffs by the waves, and having, like them, many caverns and lithodomous perforations in the hard limestone.*

Near the northern gate of the town of St. Mihiel, south of Verdun, in France, I have examined a series of markings on the face of the limestone cliffs, much resembling some of those described by M. Boblaye. There are three and sometimes four distinct horizontal grooves, which have been scooped out of a white semi-crystalline rock, or marble, of the oolitic period. This ancient cliff, which is near the right bank of the Meuse, is in part broken into a number of detached rocks, the upper parts of which present in some cases precipitous sides towards all points of the compass, round which the grooves pass in a circular course, just as if the summit of a rocky islet had been worn by the waves.†

* Journ. de Géol., No. x. Feb. 1831; Bull. de la Soc. Géol. de France, tom. ii. p. 236.

† I have no data for speculating on the period at which these cliffs may have emerged from the sea. I was directed to the spot,

Captain Bayfield, in his survey of the coast of the Gulf of St. Lawrence, traced in several places, especially in the Mingan Islands, a succession of shingle beaches, the most distant from the shore being sixty feet above the level of the highest tides. He also observed water-worn pillars of limestone accompanying these beaches, which bear evidence of having been worn and scooped out at different periods; the marks of the successive action of the water agreeing in level with the successive ridges of limestone shingle. The drawings of the pillars, made to illustrate his memoir, convince me that they are counterparts of the worn rocks which I have seen at St. Mihiel.*

If there exist lines of parallel upraised cliffs, we ought to find parallel lines of elevated beaches on those coasts where the rocks are of a nature to retain for a length of time the marks imprinted on their surface. We may expect such indications to be peculiarly manifest in countries where the subterranean force has been in activity within comparatively modern times, and it is there that the hypothesis of paroxysmal elevations, and the instantaneous rise of mountain-chains, should first have been put to the test, before it was too hastily embraced and extended.

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which I visited in June, 1833, by M. Deshayes; and I stated in the second edition, on his authority, that the worn rocks were eaten into by marine lithodomous shells, but I was unable to discover any of these; and I believe that the fossils of the genus Saxicava, which M. Deshayes procured from this place, were of the age of the corals of the limestone, not of the date of the excavation of the grooves. The fossil corals of this formation (coral rag) frequently contain lithodomous shells, which seem to have pierced the zoophytes while they were still growing in the sea.

* Proceedings of Geol. Soc., No. 33. p. 5.

West Indian Archipelago. — According to the sketch given by Maclure of the geology of the Leeward Islands, the western range consists in great part of formations of the most modern period.* It will be remembered, that many parts of this region have been subject to violent earthquakes; that in St. Vincent's and Guadaloupe there are active volcanos, and in some of the other islands boiling springs and solfataras. In St. Eustatia there is a marine deposit, estimated at 1500 feet in thickness, consisting of coral limestone alternating with beds of shells, of which the species are, according to Maclure, the same as those now found in the sea. These strata dip to the south-west, at an angle of about 45°, and both rest upon, and are covered by, cinders, pumice, and volcanic substances. Part of the madreporic rock has been converted into silex and calcedony, and is, in some parts, associated with crystalline gypsum. Alternations of coralline formations with prismatic lava and different volcanic substances also occur in Dominica and St. Christopher's; and the American naturalist remarks, that as every lava-current which runs into the sea in this archipelago is liable to be covered with corals and shells, and these again with lava, we may suppose an indefinite repetition of such alternations to constitute the foundation of each island.

I do not question the accuracy of the opinion, that the fossil shells and corals of these formations are of recent species; for there are specimens of limestone in the Museum of the Jardin du Roi at Paris, from the West Indies, in which the imbedded shells are all or nearly all identical with those now living. Part of

* Quart. Journ. of Sci., vol. v. p. 311.

this limestone is soft, but some of the specimens are very compact and crystalline, and contain only the casts of shells. Of thirty species examined by M. Deshayes from this rock, twenty-eight were decidedly recent.

Honduras. — Shells sent from some of the recent strata of Jamaica, and many from the nearest adjoining continent of the Honduras, may be seen in the British Museum, and are identified with species now living in the West Indian seas.

East Indian Archipelago. — We have seen that the Indian Ocean is one of the principal theatres of volcanic disturbance; it is to be expected, therefore, that future researches in this quarter of the globe will bring to light some of the most striking examples of marine strata upraised to great heights during comparatively modern periods.

From the observations of Dr. Jack, it appears that in the island of Pulo Nias, off the west coast of Sumatra, masses of corals of recent species can be traced from the level of the sea far into the interior, where they form considerable hills. Large shells of the Chama gigas (*Tridacna*, Lamk.) are scattered over the face of the country, just as they occur on the present reefs. These fossils are in such a state of preservation as to be collected by the inhabitants for the purpose of being cut into rings for the arms and wrists.*

Madeira. — The island of Madeira is placed between the Azores and Canaries, in both of which groups there are active volcanos; and Madeira itself was violently shaken by earthquakes during the last century.

* Geol. Trans., Second Series, vol. i. part ii. p. 397.

It consists in great part of volcanic tuffs and porous lava, intersected in some places, as at the Brazen Head, by vertical dikes of compact lava.* Some of the marine fossil shells, procured by Mr. Bowdich from this island, are referrible to recent species.

These examples may suffice for the present, and lead us to anticipate with confidence, that in almost all countries where changes of level have taken place in our own times, the geologist will find monuments of a prolonged series of convulsions during the Recent and Newer Pliocene periods. Exceptions may no doubt occur where a particular line of coast is sinking down; yet even here we may presume, from what we know of the irregular action of the subterranean forces, that some cases of partial elevation will have been caused by occasional oscillations of level, so that modern subaqueous formations will, here and there, have been brought up to view.

I shall conclude by enumerating some exceptions to the rule above illustrated, — instances of elevation where no great earthquakes have been recently experienced.

Scandinavia. — The first and most important is that of Sweden, before described in detail.† This country, although free from convulsions, was shown to be the theatre of unceasing changes in the relative level of land and sea. We accordingly discover in it deposits of sand, marl, and clay, several hundred feet in thickness, and containing recent species of marine shells raised to the height of 200 feet, and even in Norway 400 feet above the sea, and extending at some points far into the interior.

* MS. of Captain B. Hall.

† Book ii. chap. xvii.

Grosœil, near Nice. — At a spot called Grosœil, near Nice, east of the Bay of Villefranche, in the peninsula of St. Hospice, a remarkable bed of fine sand occurs at an elevation of about fifty feet above the sea.* This sand rests on inclined secondary rocks, and is filled with the remains of marine species, all identical with those now inhabiting the neighbouring sea. No less than two hundred species of shells, and several crustacea and echini, have been obtained by M. Risso, in a high state of preservation, although mingled with broken shells. The winds have blown up large heaps of similar sand to considerable heights, upon ledges of the steep coast farther westward; but the position of the deposit at Grosœil cannot be referred to such agency, for among the shells may be seen the large Murex Triton, Linn., and a species of Cassis, weighing a pound and a half.

West of England.—The proofs lately brought to light of analogous elevations on our western shores, in Caernarvonshire and Lancashire, during some comparatively modern period, were before pointed out†; but the data are as yet exceedingly incomplete.

Western borders of the Red Sea.— Another exception may be alluded to, for which we are indebted to the researches of Mr. James Burton. On the western shores of the Arabian Gulf, about half way between Suez and Kosire, in the 28th degree of north latitude, a formation of white limestone and calcareous sand is seen, reaching the height of 200 feet above the sea. It is replete with fossil shells, all of recent species, which are in a beautiful state of preservation, many of

* I examined this locality, in company with Mr. Murchison, in 1828.

† See description of the Map, Vol. I. p. 210.

them retaining their colour.* The volcano of Gabel Tor, situate at the entrance of the Arabian Gulf, is the nearest volcanic region known to me at present.

Timor.—In the island of Timor, which approaches very near to the great volcanic band traced by Von Buch†, M. Péron mentions the occurrence of corals and marine shells, apparently of recent species‡; and Dr. Fitton, in his account of Capt. King's collection of rocks from Australia, mentions a calcareous sandstone and breccia, at the height of several hundred feet above the sea, on many parts of the Australian coast.§ Future observations must decide whether these formations belong to the newest tertiary era, as conjectured. Some of the above examples certainly afford proofs of elevation, since the commencement of the Newer Pliocene period, to considerable heights, in countries far from the existing theatres of volcanic action; yet in these instances the upraised deposits containing recent shells appear in general to be confined to the coast, and not to enter largely, like those of Sicily, into the structure of mountains in the interior.

But the reader must not infer, from the facts above detailed, that marine strata of the Newer Pliocene period have been produced almost exclusively in countries of earthquakes, or where changes of level are taking place, as in Sweden. If our illustrations have been drawn chiefly from modern volcanic regions, it is

* These fossils are now in the museum of Mr. Greenough, in London, and duplicates, presented by him, in the cabinets of the Geological Society. A list of them was given in App. II., first edition.

† See Map, Vol. II.

‡ Voy. découv. des Terres Australes, vol. ii. pp.165. 183.

§ App. to Captain P. King's Australia.

simply because these formations have been made visible in those districts only where the conversion of sea into land has taken place in times comparatively modern. Other continents have, during the Newer Pliocene period, suffered degradation, and rivers and currents have deposited sediment in other seas; but the new strata remain concealed wherever no subsequent alterations of level have taken place.

Yet, to a certain limited extent, the growth of new subaqueous deposits may have been greatest where igneous and aqueous causes have co-operated. It is there that the degradation of land is most rapid, and it is there only that materials ejected from below, by volcanic explosions, are added to the sediment transported by running water.*

* See Book ii. chap. xv.; and Book iii. chap. xviii.

CHAPTER XI.

NEWER PLIOCENE FORMATIONS — FRESH-WATER AND ALLUVIAL.

Newer Pliocene fresh-water formations — Valley of the Elsa — Travertins of Rome — Loess of the Valley of the Rhine — Contains recent terrestrial and aquatic shells — Its origin — Osseous breccias of the Newer Pliocene era (p. 51.) — Fossil bones of Marsupial animals in Australian caves — Newer Pliocene alluviums (p. 57.) — European alluviums chiefly tertiary — Erratic blocks of the Alps — Theory of their transportation by ice.

Fresh-water Formations.—In this chapter I shall treat of the fresh-water formations, and of the cave breccias and alluviums of the Newer Pliocene period.

In regard to the first of these, they must have been formed, in greater or less quantity, in nearly all the existing lakes of the world; in those, at least, of which the basins were formed before the earth was tenanted, by man. If the great lakes of North America originated before that era, the sedimentary strata deposited therein, in the ages immediately antecedent, would, according to the terms of our definition, belong to the Newer Pliocene period.

Valley of the Elsa. — As an example of the strata of this age, which have been exposed to view in consequence of the drainage of a lake, I may mention those of the valley of the Elsa, in Tuscany, between Florence and Sienna, where we meet with fresh-water

marls and travertins full of shells, belonging to species which now live in the lakes and rivers of Italy. Valleys several hundred feet deep have been excavated through the lacustrine beds, and the ancient town of Colle stands on a hill composed of them. The subjacent formation consists of marine Subapennine beds, in which more than half the shells are of recent species. The fresh-water shells which I collected near Colle are in a very perfect state, and the colours of the Neritinæ are peculiarly brilliant.*

Travertins of Rome. — Many of the travertins and calcareous tufas which cap the hills of Rome may also belong to the same period. The terrestrial shells inclosed in these masses are of the same species as those now abounding in the gardens of Rome, and the accompanying aquatic shells are such as are found in the streams and lakes of the Campagna. On Mount Aventine, the Vatican, and the Capitol, we find abundance of vegetable matter, principally reeds, encrusted with calcareous tufa, and intermixed with volcanic sand and pumice. The tusk of a mammoth has been procured from this formation, filled in the interior with solid travertin, wherein sparkling crystals of augite are interspersed, so that the bone has all the appearance of having been extracted from a hard crystalline rock.†

These Roman tufas and travertins repose partly on marine tertiary strata, belonging, perhaps, to the Older Pliocene era, and partly on volcanic tuff of a still later

* The following six pieces, all of which now inhabit Italy, were identified by M. Deshayes: — *Paludina impura, Neritina fluviatilis, Succinea amphibia, Limnea auricularis, L. pereger.*, and *Planorbis carinatus.*

† This fossil was shown me by Signor Riccioli at Rome.

date. They must have been formed in small lakes and marshes, which existed before the excavation of the valleys which divide the seven hills of Rome, and they must originally have occupied the lowest hollows of the country as it then existed; whereas now we find them placed upon the summit of hills about 200 feet above the alluvial plain of the Tiber. We know that this river has flowed nearly in its present channel ever since the building of Rome, and that scarcely any changes in the geographical features of the country have taken place since that era.

When the marine tertiary strata of this district were formed, those of Monte Mario for example, the Mediterranean was already inhabited by a large proportion of the existing species of testacea. At a subsequent period, volcanic eruptions occurred, and tuffs were superimposed. The marine formation then emerged from the deep, and supported lakes wherein the freshwater groups above described slowly accumulated, at a time when the mammoth inhabited the country. The valley of the Tiber was afterwards excavated, and the adjoining hills assumed their present shape; and then a long interval may, perhaps, have elapsed before the first human settlers arrived. Thus we have evidence of a chain of events, all regarded by the geologist as among the most recent, but which, nevertheless, may have preceded, for a long series of ages, a very remote era in the history of nations.

*Loess of the valley of the Rhine.**— A remarkable

* Since the publication of the octavo edition, I have had opportunities of re-examining the loess in the country between Cologne and Heidelberg, especially near Andernach, and of studying it in several parts of Baden, Darmstadt, Wurtemberg, and Nassau. The details of these observations have been given

deposit of calcareous loam, containing land and fresh-water shells of recent species, occurs here and there, in detached patches, throughout the valley of the Rhine, between Basle and Cologne, and on the flanks of the hills bordering the great valley. This deposit is provincially termed "loess" by the Germans, and in Alsace, "lehm."

According to M. Leonhard, the loess at Heidelberg consists chiefly of argillaceous matter, combined with a sixth part of carbonate of lime, and a sixth of quartz-ose and micaceous sand. It may be described as a pulverulent loam, of a dirty yellowish-grey colour, often containing calcareous sandy concretions or nodules, rarely exceeding the size of a man's head. Its entire thickness, in some places, amounts to between 200 and 300 feet; yet there are often no signs of stratification in the mass, except here and there at the bottom, where there is occasionally a slight intermixture of drifted materials derived from subjacent rocks.

I am informed by M. Studer, that the loess does not extend into Switzerland, but the Kaiserstuhl, a group of volcanic hills, standing almost in the middle of the plain of the Rhine, south of Strasburg, is covered with it to a great height; and I have seen it in large masses near the base of the Vosges, on the left side of the plain of the Rhine, near Strasburg, and on the right side, at the base of the mountains of the Black Forest. It extends also far into Wurtemberg, up the valley of

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in a memoir read to the Geological Society in May, 1834, when I explained at length my reasons for changing and modifying some opinions formerly expressed in regard to the origin of the Löss, and its relations to the volcanic formations of the Lower Eifel.

the Neckar, and from Frankfort, up the valley of the Mayne, to above Dettelbach. In Nassau it is seen at Limburg, in the valley of the Lahn; and in Darmstadt, in the countries round Mayence, Oppenheim, and Worms.

It rises to a considerable height at Zeuten and Odenau, east of the Rhine, at a short distance from the Bergstrasse, between Wiesloch and Bruchsal, a locality first pointed out to me by Professor Bronn, where it is several hundred feet thick, and contains, both in the soft loam and in solid calcareous concretions, many shells, some of which retain occasionally their colour. The lower parts of this loess alternate with beds of alluvium derived from the degradation of the variegated sandstone and marl (bunter sandstein), of which the surrounding country is composed.

As the pure loess exhibits no divisions into strata, I at first imagined, with several other geologists, that this deposit was thrown down suddenly from the muddy waters of a transient flood, in the same manner as the moya of the Andes, or as the trass of the Rhine volcanos is generally believed to have been formed. But on re-examining the places where loess and alluvium, or loess and layers of volcanic matter alternate, I am compelled to renounce this view. In the deep gravel pits without the Manheim gate of Heidelberg, loess is seen interstratified with gravel; and here more than one bed containing land and fresh-water shells rests upon, and is covered by, a stratum of gravel, showing the effects of successive accumulation. I observed the same fact in the valley of the Lahn, north of Limburg, near the village of Elz; and Professor Bronn informs me, that the calcareous concretions of the loess are sometimes arranged in horizontal

layers, marking a difference in the carbonate of lime with which the sediment must have been charged at different periods.

Mammiferous remains are rare in the loess; but it is said that the bones of the mammoth, horse, and some other quadrupeds, have been met with: but the most characteristic fossils are land-shells; and it will naturally be asked in what manner so prodigious a quantity of such shells could become buried at various depths in a subaqueous deposit. The answer is, that the Rhine, in our own times, bears down annually to the sea thousands of empty snail-shells, washed away during heavy rains, together with the floating shells of aquatic mollusca from streams, lakes, and stagnant pools. In the summer of 1833, I collected several hundred shells, which were exposed on the margin of the Rhine, on the fall of the waters, or had been cast ashore by large waves raised by the steam-boats; and on comparing them with a still larger collection obtained from the loess, the two groups proved to be referrible for the most part to identical species, and in both the terrestrial predominated numerically over the aquatic species. The genera most abundantly represented in each were Helix, Pupa, Limnea, Paludina, and Planorbis. But among the recent shells of the Rhine, the Unio and Neritina sometimes occurred; genera of which I never found any species in the loess.

Now, it has been ascertained, that the waters of the Rhine, when evaporated, leave a residuum of calcareous loam, not distinguishable from loess*; so that, if

* See Mr. Horner, on the Sediment of the Rhine, Proceedings of Geol. Soc., 1834.

these waters should enter a lake, they might give rise to a deposit, not only containing the same shells as the loess (with the exception of some fluviatile species), but having also the same mineral characters.

The loess is found reposing on every rock, from the granite near Heidelberg, to the gravel of the plains of the Rhine. It overlies almost all the volcanic products, even those between Neuwied and Bonn, which have the most modern aspect; and it has filled up, in part, the crater of the Roderberg; at the bottom of which a well was sunk, in 1833, through seventy feet of loess. Here, as elsewhere, it is a yellow loam with calcareous concretions, and has not the character of a local alluvium.

It is remarkable, indeed, that the loess is scarcely ever affected by the nature of the rocks which underlie or immediately surround its site, but wherever it occurs appears as if derived from one common source.

On revisiting the sections near Andernach, which have been appealed to by MM. Steininger, Hibbert, and others, as proving that some of the last eruptions of the Lower Eifel took place both during and since the deposition of the loess, I found it impossible not to come to the same conclusion. The loamy sediment may be seen in the Kirchweg, above Andernach, alternating with volcanic matter, over which is a mass of pure and unmixed loess, thirty feet and upwards in thickness, containing the usual shells; and over the whole are strewed layers of pumice, lapilli, and volcanic sand, from ten to fifteen feet thick, very much resembling the ejections under which Pompeii lies buried. There is no passage at this upper junction from the loess into the pumiceous superstratum; and

this last follows the slope of the hill, just as it would have done had it fallen in showers from the air on a declivity partly formed of loess.

The greatest known height attained by the loess is near Heilbronn, where it covers the slopes of some hills two or three hundred feet above the Neckar; that river being there about 500 feet above the sea. Whatever theory we adopt to explain the position of such elevated masses, it must always be evident that great geographical changes have taken place in the countries bordering the Rhine since some of the loess was formed, and, consequently, since the recent species of terrestrial and aquatic shells were in existence.

On the other hand, when we find the loess overlying the gravel of the Rhine near Strasburg, Bonn, and other places, we are compelled to admit that a great part of it was formed after the country had acquired nearly its present configuration. The first idea which has probably occurred to every one, after examining the loess between Mayence and Basle, is, to imagine that a great lake once extended throughout the valley of the Rhine between those places, which sent off large branches up the course of the Mayne, Neckar, and other tributary valleys. The barrier of such a lake might be placed somewhere in the narrow and picturesque gorge of the Rhine between Bingen and Bonn. But this theory is insufficient to explain the phenomena; for that gorge itself has once been filled with loess, which must have been tranquilly deposited in it, as also in the lateral valley of the Lahn, communicating with the gorge. The loess has also overspread the high adjoining platform near the village of Plaidt, above Andernach. Nay, on proceeding farther to the north, we discover that the hills which

skirt the valley between Bonn and Cologne have loess on their flanks, which also covers here and there the gravel of the plain as far as Cologne.

Instead of supposing one continuous lake of sufficient extent and depth to allow of the simultaneous accumulation of the loess at various heights, throughout the whole area where it now occurs, it might be a less violent hypothesis to assume that the countries drained by the Rhine and its tributaries, after they had nearly acquired their actual form and leading geographical features, underwent great changes of level, by movements contemporaneous with the last series of volcanic eruptions of the Lower Eifel. Different parts of this region may have been alternately depressed and upraised in such a manner that they were each in their turn submerged beneath the waters of the Rhine, and covered with its sediment and floating shells. Gravel may have been intermingled in some places where the tributaries of the Rhine brought down coarser alluvium. After various tracts had thus been inundated in succession, covered with loess, and then laid dry, the larger portion of the loess must have been removed by denudation ; a process which is still going on continually, as the particles of so fine a loam allow of their being washed away very readily by rain.

It is not, I think, impossible that some of the newly-formed lakes in the basin of Red River, in Louisiana, before described, may have been occasioned by changes in the relative level of the lands there flooded ; for the valley of the Mississippi is one of the modern theatres of earthquakes.* Now, the course of Red River far

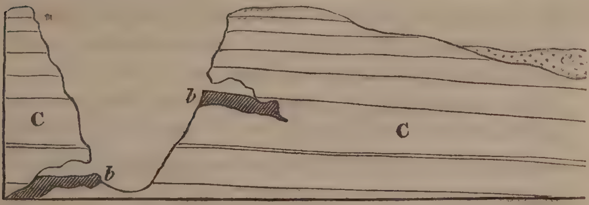
* Vol. I. p. 286.

exceeds in length, and is indeed nearly double, that of the Rhine; and whatever may be the causes which are giving rise to the successive submergence of its plains, they must also occasion the accumulation in many parts of that great valley of the red ochreous sediment so peculiar to Red River.

If the fluctuations in the relative levels of this great American valley should, in the course of ages, be so important as to produce elevations and subsidences to the amount of several hundred feet, the results, in regard to the superficial distribution of red fluviatile mud, might be very analogous to those observed in the position of the yellow loess in the valley of the Rhine above considered.*

Osseous breccias — Sicily. — The breccias lately found in several caves in Sicily belong evidently to the period under consideration. I have shown, in the sixth chapter, that the cavernous limestone of the Val di Noto is of very modern date, as it contains a

Fig. 90.



a. Alluvium, *b, b*. Deposits in caves, } containing remains of *extinct* quadrupeds.
C. Limestone containing remains of *recent* shells.

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* For particulars concerning the loess of the Rhine, consult the works of MM. Bronn, Leonhard, Boué, Voltz, Noeggerath, Steininger, Merian, Rozet, Von Meyer, and Hibbert.

great abundance of fossil shells of recent species; and if any breccias are found in the caverns of this rock, they must be of still later origin.

We are informed by M. Hoffmann, that the bones of the mammoth, and of an extinct species of hippopotamus, have been discovered in the stalactite of caves near Sortino, of which the situation is represented in the annexed diagram at *b*. The same author also describes a breccia, containing the bones of an extinct rhinoceros and hippopotamus, in a cave in the neighbourhood of Syracuse, where the country is composed entirely of the Val di Noto limestone. Some of the fragments in the breccia are perforated by lithodomi, and the whole mass is covered by a deposit of marine clay filled with recent shells.* These phenomena may, I think, be explained by supposing such oscillations of level as are known to occur on maritime coasts where earthquakes prevail — such, in fact, as have been witnessed on the shores of the Bay of Baiæ within the last three centuries.† For it is evident that the temporary submergence of a cave filled with osseous breccia might afford time for the perforation of the rock by boring testacea, and for the deposition upon it of mud, sand, and shells.

The association in these and other localities of shells of living species with the remains of extinct mammalia is very distinct, and corroborates the inference adverted to in a former chapter, that the longevity of *species* in the mammalia is, upon the whole, inferior to that of the testacea. I am by no means

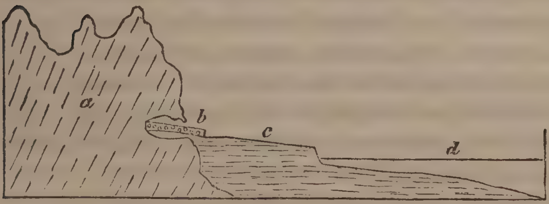
* Hoffmann, Archiv für Mineralogie, p. 393. Berlin, 1831. Dr. Christie, Proceedings of Geol. Soc., No. xxiii. p. 333.

† Vol. II. p. 312.

inclined to refer this circumstance to the intervention of man, and his power of extirpating the larger quadrupeds; for the succession of mammiferous species appears to have been in like manner comparatively rapid throughout the older tertiary periods. Their more limited duration depends, in all probability, on physiological laws, which render warm-blooded quadrupeds less capable, in general, of accommodating themselves to a great variety of circumstances, and, consequently, of surviving the vicissitudes to which the earth's surface is exposed in a great lapse of ages.*

Caves near Palermo. — The caves near Palermo exhibit appearances very analogous to those above described, and much curious information has been

Fig. 91.



a. Monte Grifone. *b.* Cave of San Ciro.
c. Plain of Palermo, in which are Newer Pliocene strata of limestone and sand.
d. Bay of Palermo. †

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* See Vol. III. p. 121., and book i. chap. vi.

† This section is given by the late Dr. Christie, as of the Cave of San Ciro. Ed. New Phil. Journ., No. xxiii. It was called by mistake the Cave of Mardolce, by M. Hoffmann. An account has since appeared by Mr. S. P. Pratt, F.G.S.: see the Proceedings of Geol. Soc. of London, No. 32. 1833.

lately published respecting them. According to Hoffmann, the grotto of San Ciro is distant about two miles from Palermo, and is twenty feet high and ten wide. It occurs in a secondary limestone, in the Monte Grifone, at the base of a rocky precipice about 180 feet above the sea. From the foot of this precipice an inclined plane, consisting of horizontal tertiary strata, of the Newer Pliocene period, extends to the sea, a distance of about a mile.

The limestone escarpment was evidently once a sea-cliff, and the ancient beach still remains formed of pebbles of various rocks, many of which must have been brought from places far remote. Broken pieces of coral and shell, especially of oysters and pectens, are seen intermingled with the pebbles. Immediately above the level of this beach, serpulæ are still found adhering to the face of the rock, and the limestone is perforated by lithodomi. Within the grotto, also, at the same level, similar perforations occur; and so numerous are the holes, that the rock is compared by Hoffmann to a target pierced by musket balls. But in order to expose to view these marks of boring-shells in the interior of the cave, it was necessary first to remove a mass of breccia, which consisted of numerous fragments of rock and an immense quantity of bones imbedded in a dark brown calcareous marl. Many of the bones were rolled as if partially subjected to the action of the waves. Below this breccia, which is about twenty feet thick, was found a bed of sand filled with sea-shells of recent species; and underneath the sand, again, is the secondary limestone of Monte Grifone. The state of the surface of the limestone in the cave above the level of the marine sand is very different from that below it. *Above,* the rock is jagged and

uneven, as is usual in the roofs and sides of limestone caverns; *below*, the surface is smooth and polished, as if by the attrition of the waves.

So enormous was the quantity of bones, that many ship-loads were exported in the years 1829 and 1830, in the hope of their retaining a sufficient quantity of gelatine to serve for refining sugar; for which, however, they proved useless. The bones belong chiefly to the mammoth (*E. primigenius*), and with them are those of an hippopotamus, distinct from the recent species, and smaller than that usually found fossil. Several species of deer, also, and, according to some accounts, the remains of a bear, were discovered.

It is easy to explain in what manner the cavern of San Ciro was in part filled with sea-sand, and how the surface of the limestone became perforated by lithodomi; but in what manner, when the elevation of the rocks and the ancient beach had taken place, was the superimposed osseous breccia formed? For want of more exact local details, it would be rash to speculate on this subject; but by referring to what was previously said of cavrens near the sea-shore of the Morea, from which rivers escape, the reader may conceive that caves, after having been submerged and filled with sea-sand, may afterwards be upraised and flooded by the waters of engulphed rivers washing down animal remains from the land.*

Two other caverns are described by Dr. Christie as occurring in Mount Beliemi, about four miles west of Palermo, at a higher elevation than that of San Ciro, being more than three hundred feet above the level of

* See Vol. III. p. 228.

the sea. In one of these places the bones are found only in a talus at the outside of the cavern; in the other, they occur both within the cave and in the talus which slopes from it to the plain below. These caves appear to be situated much above the highest point attained by the tertiary deposits in this neighbourhood; nor is there the slightest appearance in the caves themselves of the sea having been there.*

Australian cave-breccias.—Ossiferous breccias have lately been discovered in fissured and cavernous limestone in Australia, and the remains of the fossil mammalia are found to be referrible to species now living in that country, mingled with some relics of extinct animals. Some of these caves have been examined by Major Mitchell, in the Wellington Valley, about 210 miles west of Sydney, on the river Bell, one of the principal sources of the Macquarie, and on the Macquarie itself.

The fissures and caverns appear to correspond closely with those which contain similar osseous breccias in Europe: they often branch off in different directions through the rock, widening and contracting their dimensions, the roofs and floors being covered with stalactite. The bones are often broken, but do not seem to be water-worn. In some caves and fissures they lie imbedded in loose earth, but usually they are included in a breccia, having a red ochreous cement as hard as limestone, and like that of the Mediterranean caves.

The remains found most abundantly are those of the kangaroo. Amongst others, those of the Wombat

* Dr. T. Christie, on certain Newer Deposits in Sicily, &c.—Jameson, Ed. New Phil. Jour., No. xxiii. p. 1.

Dasyurus, Kaola, and Phalangista, have been recognized. The greater part of them belong to existing, but some to extinct, species. One of the latter bones, of much greater size than the rest, is supposed, by Mr. Clift, to belong to an hippopotamus.*

In a collection of these bones sent to Paris, Mr. Pentland thought he could recognize a species of Halmaturus exceeding in size the largest living kangaroo.†

These facts are full of interest, for they prove that the peculiar type of organization which now characterizes the marsupial tribes has prevailed from a remote period in Australia; and that in that continent, as in Europe, North and South America, and India, some species of mammalia have become extinct. It also appears, although the evidence on this point is still incomplete, that among the extinct were land quadrupeds far exceeding in magnitude any of the wild animals now inhabiting New Holland.‡

Newer Pliocene Alluviums. — Some writers have attempted to introduce into their classification of geological periods an *alluvial epoch*, as if the transportation of loose matter from one part of the surface of the land to another had been the work of one particular period.

With equal propriety might they have endeavoured to institute a volcanic period, or a period of marine

* Mr. Clift, Ed. New Phil. Journ., No. xx. p. 394. Major Mitchell, Proceedings of Geol. Soc., 1831, p. 321.

† Journ. de Géologie, tome iii. p. 291. The bone mentioned as that of an *elephant* by Mr. Pentland, was the same large bone alluded to by Mr. Clift.

‡ For remarks on the mode in which these caverns may have been filled with osseous breccias, see Vol. III. p. 225.

or freshwater deposition; for alluvial formations must have originated in every age, since the surface of the earth was first divided into land and sea, but most rapidly in any given district at those periods when land has been upheaved above, or depressed below, its former level.*

If those geologists who speak of an "alluvial epoch" intend merely to say that a great part of the European alluviums are *tertiary*, there may undoubtedly be some truth in the opinion; for the larger part of the existing continent of Europe has emerged from beneath the waters during some one or other of the tertiary periods †; and it is probable, that even those districts which were land before the commencement of the tertiary epoch, may have shared in the subterranean convulsions by which the levels of adjoining countries have since been altered. During such subterranean movements new alluviums might be formed in great abundance, and those of more ancient date so modified as to retain scarcely any of their original distinguishing characters.

During the gradual rise of a large area, first from beneath the waters, and then to a great height above them, several kinds of superficial gravel must be formed and transported from one place to another. When the first islets begin to appear, and the breakers are foaming upon the new-raised reefs, many rocky fragments are torn off and rolled along the bottom of the sea.

Let the reader recall to mind the action of the tides and currents off the coast of Shetland, where blocks of granite, gneiss, porphyry, and serpentine, of enor-

* See definition of alluvium, Vol. III. p. 218.

† See map, Vol. I. p. 209.

mous dimensions, are continually detached from wasting cliffs during storms, and carried in a few hours to a distance of many hundred yards from the parent rocks.* Suppose the floor of the ocean, after being thus strewed over with detached blocks and pebbles, to be converted partially into land, the geologist might then, perhaps, search in vain for the masses from which the fragments were originally derived, since part of these may have been consumed by the waves, and the rest may remain submerged beneath them.

If this new land be then uplifted to a considerable height, the marine alluvium before alluded to would be raised up on the summits of the hills and on the surface of elevated platforms. It might still constitute the general covering of the country, being wanting only in such valleys and ravines as may have been caused by earthquakes, or excavated by the power of running water during the rise of the land; for the alluvium in those more modern valleys would consist partly of pebbles washed out of the older gravel before mentioned, but chiefly of fragments derived from the rocks which were removed during the erosion of the valleys themselves.

Erratic blocks.—Blocks of extraordinary magnitude have been observed at the foot of the Alps, and at a considerable height in some of the valleys of the Jura, exactly opposite the principal openings by which great rivers descend from the Alps. These fragments have been called "erratic," and many imaginary causes have been invented to account for their transportation. Some have talked of chasms opening in the ground immediately below, and of huge fragments

* See Vol. III. p. 12.

having been cast out of them from the bowels of the earth. Others have referred to the deluge, an agent in which a simple solution is so often found of every difficult problem exhibited by alluvial phenomena; and more recently, the sudden rise of mountain-chains has been introduced as a cause which may have given rise to diluvial waves, capable of devastating whole continents, and drifting huge blocks from one part of the earth's surface to another.

It seems necessary to suppose that the Jura once formed a prolongation of the Alps, and that large fragments of rock were, at a remote period, detached from the Alpine summits, and transported to lower hills or platforms, which were destined afterwards to be upraised and to form the independent chain now called the Jura. Ice, as has been often suggested, may have contributed its aid to the transfer of such blocks; for some of the masses are so enormous, that not even a flood like that in the valley of Bagnes, in 1818 *, can be supposed to have conveyed them to considerable distances by the power of water alone.

That the Alps must have been moved and shaken by earthquakes at periods comparatively modern, is evident from the fact that they are skirted on their northern, southern, and eastern flanks by marine tertiary strata. When these were raised into their present position, to the height of many hundred feet above the sea, the whole of the older chain must have participated in the convulsions.

It is important, therefore, to consider what would now happen if regions like that of Mont Blanc were subjected to earthquakes. Large fragments of rock,

* See Vol. I. p. 291.

detached by the action of rain and frost from the peaks "or needles," as they are called, of Chamouni, fall annually on the surface of the glaciers, and are gradually transported by ice to the distance of many leagues into the valleys below.* The shock of an earthquake would throw down a prodigious load of similar but far heavier masses, accompanied by avalanches of snow and ice, by which the moraine of the glacier would be greatly enlarged. If the shocks took place on the eve of a thaw in spring, when the accumulated snows of winter were beginning to melt, they would cause almost every where immense avalanches, by which many narrow gorges might be choked up, so that the valleys above such barriers of snow, ice, and rock would be converted into lakes. Portions of the rent glaciers, moreover, would at their lower extremities be covered with water, and might be floated off together with incumbent and included fragments of rock. At length, on the bursting of the temporary barrier, the whole mass of waters, together with huge rocks buoyed up by ice, would descend with tremendous violence into the lower country.

The manner in which the ice of rivers and of the sea itself contributes, in the Baltic and other northern regions, to transport large blocks, as well as smaller pieces of stone, to vast distances, has been treated of in a former chapter.†

Sicily.—Assuming, then, that almost all the European alluviums are tertiary, we have next to inquire which of them are of Newer Pliocene origin. It is clear that, when a district, like the Val di Noto, is composed of rocks of this age, all the alluvium upon

* Vol. I. p. 265. † See Vol. I. p. 267.

the surface must necessarily belong either to the Newer Pliocene or the Recent epoch. If, therefore, the elevation of the mountains of the Val di Noto was chiefly accomplished antecedently to the Recent epoch, we must at once pronounce all alluviums, in the position indicated at *a*, Fig. 90. (p. 51.), to belong to the Newer Pliocene era. I saw gravel so situated at Grammichele in Sicily, and was informed that it contained the bones of the mammoth.

Sweden.—I also believe that a large portion of what is usually termed diluvium, spread over the land bordering the eastern and western coasts of Sweden, may properly be called alluvium of the Recent and Newer Pliocene periods.

CHAPTER XII.

OLDER PLIOCENE FORMATIONS.

Geological monuments of the *older* Pliocene period — Subapennine formations — Opinions of Brocchi — Different groups termed by him Subapennine are not all of the same age — Mineral composition of the Subapennine formations — Marls — Yellow sand and gravel — Subapennine beds, how formed (p. 70.) — Illustration derived fromt he Upper Val d'Arno — Organic remains of Subapennine hills — Older Pliocene strata at the base of the Maritime Alps — Genoa (p. 77.) — Savona — Albenga — Nice — Conglomerate of Valley of Magnan — Its origin — Tertiary strata at the eastern extremity of the Pyrenees.

Subapennine strata. — We must now carry our retrospect one step farther, and treat of the monuments of the era immediately antecedent to that last considered. The Apennines, it is well known, are composed chiefly of secondary rocks, forming a chain which branches off from the Ligurian Alps and passes down the middle of the Italian peninsula. At the foot of these mountains, on the side both of the Adriatic and the Mediterranean, are found a series of tertiary strata, which form, for the most part, a line of low hills occupying the space between the older chain and the sea. Brocchi, the first Italian geologist who described this newer group in detail, gave it the name of the Subapennines; and he classed all the tertiary strata of Italy from Piedmont to Calabria, as parts of the same system. Certain mineral characters, he observed, were

common to the whole; for the strata consist generally of light brown or blue marl, covered by yellow calcareous sand and gravel. There are also, he added, some species of fossil shells which are found in these deposits throughout the whole of Italy.

In a catalogue, published by Lamarck, of five hundred species of fossil-shells of the Paris basin, a small number only were enumerated as identical with those of Italy, and only twenty as agreeing with living species. This result, said Brocchi, is wonderful, and very different from that derived from a comparison of the fossil-shells of Italy, *more than half of which* agree with species now living in the Mediterranean, or in other seas chiefly of hotter climates.*

He also stated, that it appeared from the observations of Parkinson, that the clay of London, like that of the Subapennine hills, was covered by sand (alluding to the crag), and that in that upper formation of sand in England the species of shells corresponded much more closely with those now living in the ocean than did the species of the subjacent clay. Hence he inferred that an interval of time had separated the origin of the two groups. But in Italy, he goes on to say, the shells found in the marl and superincumbent sand belong entirely to the same group, and must have been deposited under the same circumstances.†

Notwithstanding the correctness of these views, Brocchi conceived that the Italian tertiary strata, as a whole, might agree with those of the basins of Paris and London; and he endeavoured to explain the discordance of their fossil contents by remarking, that the

* Conch. Foss. Subap., tom. i. p.148.

† Ibid., p. 147.

testacea of the Mediterranean differ now from those living in the ocean.* In attempting thus to assimilate the age of these distinct groups, he was evidently influenced by his adherence to the anciently received theory of the gradual fall of the level of the ocean, to which, and not to the successive rise of the land, he attributed the emergence of the tertiary strata; all of which he consequently imagined to have remained under water down to a comparatively recent period.

Brocchi was perfectly justified in affirming that there were some species of shells common to all the strata called by him Subapennine; but I have shown that this fact is not inconsistent with the conclusion, that the several deposits may have originated at different periods, for there are species of shells common to all the tertiary eras. He seems to have been aware, however, of the insufficiency of his data; for in giving a list of species universally distributed throughout Italy, he candidly admits his inability to determine whether the shells of Piedmont were all identical with those of Tuscany, and whether those of the northern and southern extremities of Italy corresponded.†

We have already satisfactory evidence that the Subapennine beds of Brocchi belonged, at least, to three periods. To the Miocene we can refer a portion of the strata of Piedmont, those of the hill of the Superga, for example; to the Older Pliocene belong the greater part of the strata of northern Italy and of Tuscany, and perhaps those of Rome; to the Newer Pliocene, the tufaceous formations of Naples, the calcareous strata of Otranto, and probably the greater part of the tertiary beds of Calabria.

* Conch. Foss. Subap., tom. i. p. 166. † Ibid., p. 143.

That there is a considerable correspondence in the arrangement and mineral composition of these different Italian groups, is undeniable; but not that close resemblance which should lead us to assume an exact identity of age, even had the fossil remains been less dissimilar.

Very erroneous notions have been entertained respecting the contrast between the lithological characters of the Italian strata and certain groups of higher antiquity. Dr. Macculloch has treated of the Italian tertiary beds under the general title of "elevated submarine alluvia;" and the overlying yellow sand and gravel may, according to him, be wholly, or in part, a terrestrial alluvium.* Had he visited Italy, I am persuaded that he would never have considered the tertiary strata of London and Paris as belonging to formations of a different order from the Subapennine groups, or as being more regularly stratified. He seems to have been misled by Brocchi's description, who contrasts the more crystalline and solid texture of the older secondary rocks of the Apennines with the loose and incoherent nature of the Subapennine beds, which resemble, he says, the mud and sand now deposited by the sea.

I have endeavoured, in a former chapter, to restrict within definite limits the meaning of the term *alluvium* †; but if the Subapennine beds are to be designated "marine alluvia," the same name might, with equal propriety, be applied not only to the argillaceous and sandy groups of the London and Hampshire basins, but to a very great portion of our se-

* Syst. of Geol., vol. i. chap. xv.

† Vol. III. p. 218.

condary series where the marls, clays, and sands are as imperfectly consolidated as are the tertiary strata of Italy in general.

They who have been inclined to associate the idea of the more stony texture of stratified deposits with a comparatively higher antiquity, should consider how dissimilar, in this respect, are the tertiary groups of London and Paris, although admitted to be of contemporaneous date; or they should visit Sicily, and behold a soft brown marl, identical in mineral character with that of the Subapennine beds, underlying a mass of solid and regularly stratified limestone, rivalling the chalk of England in thickness. This Sicilian marl is older than the superincumbent limestone, but newer than the Subapennine marl of the north of Italy; for in the latter the extinct shells rather predominate over the recent, in the Sicilian strata the recent species predominate almost to the exclusion of the extinct.

Subapennine marls. — I shall now consider more particularly the characters of those Subapennine beds which may be referred to the Older Pliocene period.

The most important member of the Subapennine formation is a marl which varies in colour from greyish brown to blue. It is very aluminous, and usually contains much calcareous matter and scales of mica. It often exhibits no lines of division throughout a considerable thickness, but in other places it is thinly laminated. Near Parma, for example, I have counted thirty distinct laminæ in the thickness of an inch. In some of the hills near that city the marl attains, according to Signor Guidotti, a thickness of nearly two thousand feet, and is charged throughout with shells, many of which are such as inhabit a deep sea. They often occur in layers in such a manner as to

indicate their slow and gradual accumulation. They are not flattened, but are filled with marl. Beds of lignite are sometimes interstratified, as at Medesano, four leagues from Parma; subordinate beds of gypsum also occur in many places, as at Vigolano and Bargone, in the territory of Parma, where they are interstratified with shelly marl and sand. At Lezignano, in the Monte Cerio, the sulphate of lime is found in lenticular crystals, in which unaltered shells are sometimes included. Signor Guidotti, who showed me specimens of this gypsum, remarked, that the sulphuric acid must have been fully saturated with lime when the shells were enveloped, so that it could not act upon the shell. According to Brocchi, the marl sometimes passes from a soft and pulverulent substance into a compact limestone, but it is rarely found in this solid form.* It is also occasionally interstratified with sandstone.

The marl constitutes very frequently the surface of the country, having no covering of sand. It is sometimes seen reposing immediately on the Apennine limestone; more rarely gravel intervenes, as in the hills of San Quirico.† Volcanic rocks are here and there superimposed, as at Radicofani, in Tuscany, where a hill composed of marl, with some few shells interspersed, is capped by basalt. Several of the volcanic tuffs in the same place are so interstratified with the marls as to show that the eruptions took place in the sea during the Older Pliocene period. At Acquapendente, Viterbo, and other places, hills of the same formation are capped with trachytic lava, and

* Conch. Foss. Subap., tom. i. p. 82. † Ibid., p. 78.

with tuffs which appear evidently to have been subaqueous.

Yellow sand. — The other member of the Subapennine group, the yellow sand and conglomerate, constitutes, in most of the places where I have seen it, a border formation near the junction of the tertiary and secondary rocks. In some cases, as near the town of Sienna, we see sand and calcareous gravel resting immediately on the Apennine limestone, without the intervention of any blue marl. Alternations are there seen of beds containing fluviatile shells, with others filled exclusively with marine species; and I observed oysters attached to many of the pebbles of limestone. This appears to have been a point where a river, flowing from the Apennines, entered the sea in which the tertiary strata were formed.

Between Florence and Poggibonsi, in Tuscany, there is a great range of conglomerate of the Subapennine beds, which is seen for eleven miles continuously from Casciano to the south of Barberino. The pebbles are chiefly of whitish limestone, with some sandstone. On receding from the older Apennine rocks, the conglomerate passes into yellow sand and sandstone, with shells, the whole overlying blue marl. In such cases we may suppose the deltas of rivers and torrents to have gained upon the bed of a sea where blue marl had previously been deposited.

The upper arenaceous group above described sometimes passes into a calcareous sandstone, as at San Vignone. It contains lapidified shells more frequently than the marl, owing probably to the more free percolation of mineral waters, which often dissolve and carry away the original component elements of fossil bodies and substitute others in their place. In some

cases the shells imbedded in this group are silicified, as at San Vitale, near Parma, from whence I saw two individuals of recent species, one fresh-water and the other marine (Limnea palustris, and Cytherea concentrica, Lamk.), both perfectly converted into flint.

On the other hand, the shells of Monte Mario, near Rome, which are probably referrible to the same formation, are changed into calcareous spar, the form being preserved notwithstanding the crystallization of the carbonate of lime.

Mode of formation of the Subapennine beds. — The tertiary strata above described have resulted from the waste of the secondary rocks which now form the Apennines, and which had become dry land before the Older Pliocene beds were deposited. In the territory of Placentia we have an opportunity of observing the kind of sediment which the rivers are now bringing down from the Apennines. The tertiary marl of that district being too calcareous to be used for bricks or pottery, a substitute is obtained by conveying into tanks the turbid waters of the rivers Braganza, Parma, Taro, and Enza. In the course of a year a deposit of brown clay, much resembling some of the Subapennine marl, is procured, several feet in thickness, divided into thin laminæ of different shades of colour.

In regard to the sand and gravel, we see yellow sand thrown down by the Tiber near Rome, and by the Arno, at Florence. The northern part of the Apennines consists of a grey micaceous sandstone with an argillaceous base, alternating with shale, from the degradation of which brown clay and sand would result. If a river flow through such strata, and some one of its tributaries drains the ordinary limestone of the Apennines, the clay might become marly by the

intermixture of calcareous matter. The sand is frequently yellow from being stained by oxide of iron; but this colour is by no means constant.

The similarity in composition of the tertiary strata in the basins of the Po, the Arno, and the Tiber, is merely such as might be expected to arise from their having been all derived from the disintegration of the same continuous chain of secondary rocks. But it does not follow that the latter rocks were all upheaved and exposed to degradation at the same time. The correspondence of the tertiary groups consists in their being all alike composed of marl, clay, and sand; but we might say as much of the beds of the London and Hampshire basins, although the English and Italian groups, thus compared, belong nearly to the two opposite extremes of the tertiary series.

The similarity in mineral character of the lacustrine deposit of the Upper Val d'Arno, and the marine Subapennine hills of northern Italy, ought to serve as a caution to the geologist, not to infer too hastily a contemporaneous origin from identity of mineral composition. The deposit of the Upper Val d'Arno occurs nearly at the bottom of a deep narrow valley, which is surrounded by precipitous rocks of secondary sandstone and shale (the macigno of the Italians, and greywacké of the Germans). Hills of yellow sand, of considerable thickness, appear around the margin of the small basin; while, towards the central parts, where there has been considerable denudation, and where the Arno flows, blue clay is seen underlying the yellow sand. The shells are of fresh-water origin, but I shall speak more particularly of them when discussing the probable age of this formation in the sixteenth chapter. I desire at present to call attention

to the fact, that we have here, in an isolated basin, such a formation as would result from the waste of the contiguous secondary rocks of the Apennines, fragments of which rocks are found in the sand and conglomerate. We might expect that, if the fresh-water beds were removed, and the barrier of the lake-basin closed up again, similar sediment would be again deposited; since the aqueous agents would operate in the same manner, at whatever period they might be in activity. Now, the only difference in mineral composition, between the lacustrine deposit and the ordinary marine Subapennine strata, consists in the absence of calcareous matter from the clay ; and this may be ascribed to the circumstance that the torrents flowing into the lake had passed over no limestone rocks.

The lithological character of the Subapennine beds varies in different parts of the Peninsula both in colour and degree of solidity. The presence, also, or absence of lignite and gypsum, and the association or non-association of volcanic rocks, are causes of great local discrepancy. The superposition of the sand and conglomerate to the marl, on the other hand, is a general point of agreement, although there are exceptions to the rule, as at San Quirico before mentioned. The cause of this arrangement may be, as I before hinted, that the arenaceous groups were first formed on the coast where rivers entered ; and when these pushed their deltas farther out, they threw down the sand upon part of the bed of the sea already occupied by finer and more transportable mud.

Captain Bayfield, in his Survey of the Coast of St. Lawrence, mentions horizontal strata of sand and gravel, and a subjacent deposit of clay as reposing in depressions in the older rocks near the shore. The

Plate I

1. 2. *Turbo rugosus. Lin:* _ 3. 4. *Trochus mágus. Lin:* _ 5. *Solarium variegatum. Lam.k* 6. *Tornatella fasciata. Lam.k* _ 7. *Pleurotoma vulpecula. Broc:* _ 8. *Fusus crispus. Bors:* 9. *Buccinum prismaticum. Bors:* _ 10. *Pleurotoma rotata. Broc:* _ 11. *Buccinum semi-striatum Broc:* _ 12. *Mitra plicatula. Broc:* _ 13. *Caſsidaria echinophora Lam.k* _ 14. *Cytherea exoleta. Lam.k var.*

London Published by John Murray Dec.r 1831.

clay invariably occupies the lowest position, and the gravel the highest; and this arrangement, he says, may be explained by considering that the rivers where they now bring down alluvial matter on several parts of this coast, carry gravel over a bottom previously occupied by clay, the finer sediment having first been drifted farther from the shore.*

When Captain Bayfield proposed this theory, he had not seen my work just then published†; it was satisfactory therefore to observe the exact coincidence of his views with my own, his having been suggested by the modern changes going on in the St. Lawrence, mine by reasoning on appearances in the interior of Italy.

Organic remains. — Figures of some of the most abundant shells of the Subapennine formations are given in the accompanying plate. (Pl. X.) The greater part of them are common both to the Older and Newer Pliocene periods of this work. Eight of the species, Nos. 1, 3, 5, 6, 7, 9, 13, and 14, are now living, but are also common in the *older* Pliocene formations. Fusus crispus has not been found either *recent,* or in the Miocene or Eocene formations, but occurs both in the Older and Newer Pliocene formations. Mitra plicatula has been observed only in the Older Pliocene deposits. The Turbo rugosus was formerly considered as exclusively Pliocene; but M. Boué has since found it in the Miocene strata at Vienna and Moravia. Buccinum semistriatum is also a Miocene shell, but has been inserted as being peculiarly abundant in the Pliocene strata.

The Subapennine testacea are referrible to species

* An abstract of this paper will be found in the Proceedings of the Geol. Soc., No. 33. p. 4.

† First edition of 3d Vol. p. 162.

and families of which the habits are extremely diversified, some living in deep, others in shallow water, some in rivers or at their mouths. I have seen a specimen of a *fresh-water* univalve (*Limnea palustris*), taken from the blue marl near Parma, full of small *marine* shells. It may have been floated down by the same causes which carried wood and leaves into the ancient sea.

I have been informed, by experienced collectors of the Subapennine fossils, that they invariably procure the greatest number in those winters when the rains are most abundant; an annual crop, as it were, being washed out of the soil to replace those which the action of moisture, frost, and the rays of the sun soon reduce to dust upon the surface.

The shells, in general, are soft when first taken from the marl, but they become hard when dried. The superficial enamel is often well preserved, and many shells retain their pearly lustre, and part of their external colour, and even the ligament which unites the valves. No shells are more usually perfect than the microscopic, which abound near Sienna, where more than a thousand full-grown individuals are sometimes poured out of the interior of a single univalve of moderate dimensions. In some large tracts of yellow sand it is impossible to detect a single fossil, while in other places they occur in profusion.

Blocks of Apennine limestone are found in this formation drilled by lithodomous shells. The remains not only of testacea and corals, but of fishes and crabs, are met with, as also those of cetacea, and even of terrestrial quadrupeds.

A considerable list of the mammiferous species has been given by Brocchi and some other writers; and,

although several mistakes have been made, and some bones of cetacea have been confounded with those of land animals, it is still indubitable that some remains of land animals were carried down into the sea when the Subapennine sand and marl were accumulated. The same causes which drifted skeletons into lakes, such as that of the Upper Val d'Arno, may have carried down others into firths or bays of the sea. The femur of an elephant has been disinterred with oysters attached to it, showing that it remained for some time exposed after it was drifted into the sea.

Strata at the base of the Maritime Alps.—If we pass from the Italian peninsula, and, following the borders of the Mediterranean, examine the tertiary strata at the foot of the Maritime Alps, we find formations agreeing in zoological characters with the Subapennine beds, and presenting many points of analogy in their mineral composition. The Alps, it is well known, terminate abruptly in the sea, between Genoa and Nice, and the steep declivities of that bold coast are continued below the waters; so that a depth of many hundred fathoms is often found within stone's-throw of the beach. Exceptions occur only where streams and torrents enter the sea; and at these points there is always a low level tract, intervening between the mouth of the stream and the precipitous escarpment of the mountains.

In travelling from France to Genoa, by the new coast road, we are conveyed principally along a ledge excavated out of a steep slope or precipice, in the same manner as on the roads which traverse the great interior passes of the Alps, such as the Simplon and Mont Cenis; the difference being that, in this case, the traveller has always the sea below him, instead of a

river. But we are obliged occasionally to descend by a zigzag course into those low plains before alluded to, which, when viewed from above, have the appearance of bays deserted by the sea. They are surrounded on three sides by rocky eminences, and the fourth is open to the sea.

These leading features in the physical geography of the country are intimately connected with its geological structure. The rocks composing the Alpine declivities belong partly to the primary formations, but more generally to the secondary, and have undergone immense disturbance; but when we examine the low tracts before mentioned, we find the surface covered with great beds of gravel and sand, such as are now annually brought down by torrents and streams in the winter, and which are spread in such quantity over the wide and shifting river-channels as to render the roads for a season impassable. The first idea which naturally suggests itself, on viewing these plains, is to imagine them to be deltas or spaces converted into land by the accumulated sand and gravel brought down from the Alps by rivers. But, on closer inspection, we find that the apparent lowness of the plains, which at first glance might be supposed to be only just raised above the level of the sea, is a deception produced by contrast. The Alps rise suddenly to the height of several thousand feet with a bold and precipitous outline; while the country below is composed of horizontal strata, which have either a flat or gently undulating surface. These strata consist of gravel, sand, and marl, filled with marine shells, and they are considerably elevated, attaining sometimes the height of two hundred feet, or even more, above the level of the sea; there must, therefore, have been a rise of the coast since they were deposited, and they are not mere deltas or spaces re-

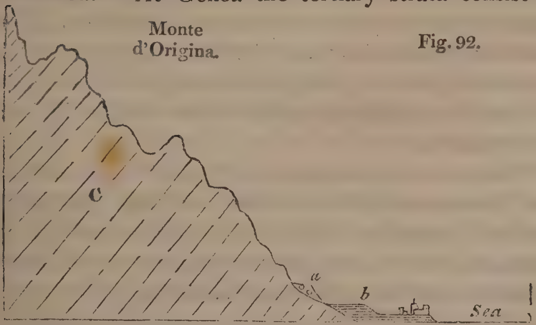
claimed from the sea by rivers. Why, then, are such strata found only at the points where rivers enter?

We must imagine that, after the coast had nearly acquired its present configuration, the streams which flowed down into the Mediterranean produced shoals opposite their mouths by the continual drifting in of gravel, sand, and mud. The Alps have since been raised to a sufficient height to cause these shoals to become land; while the corresponding elevation of the intervening parts of the coast, where the sea was of great depth near the shore, has not been perceptible.

The disturbing force appears to have acted very irregularly, and to have produced the least elevation towards the eastern extremity of the Maritime Alps, and a greater amount as we proceed westward. Thus we find the marine tertiary strata attaining the height of about 100 feet at Genoa, 200 and 300 feet farther westward at Albenga, and 800 or 900 feet in the neighbourhood of Nice.

Genoa. — At Genoa the tertiary strata consist of

Fig. 92.



Position of tertiary strata at Genoa.

a. Ancient sea-beach. *b.* Blue marl with shells.
C. Inclined secondary strata of sandstone, shale, &c.

blue marls like those of the northern Subapennines and contain the same shells. On the immediate site of the town they rise to the height of only twenty feet above the sea; but they reach about eighty feet in some parts of the suburbs. At the base of a mountain not far from the suburbs there is an ancient beach, strewed with rounded blocks of Alpine rocks, some of which are drilled by the *Modiola lithophaga*, Lamk., the whole cemented into a conglomerate, which marks the ancient sea-beach at the height of 100 feet above the present sea.*

Savona. — At Savona, proceeding westwards, we find deposits of blue marl like those of Genoa, and occupying a corresponding geological position at the base of the mountains near the sea. The shells, collected from these marls by Mr. Murchison and myself, in 1828, were examined by Signor Bonelli, of Turin, and found to agree with Subapennine fossils.

Albenga. — At Albenga these formations occupy a more extensive tract, forming the plains around that town and the low hills of the neighbourhood, which reach in some spots an elevation of 300 feet. The encircling mountains recalled to my mind those which bound the plain and bay of Palermo, and other bays of the Mediterranean, which are surrounded by bold rocky coasts.

The general resemblance of the Albenga strata to the Subapennine beds is very striking; the lowest division consisting of blue marl which is covered by sand and yellow clay, and the highest by a mass of stratified shingle, sometimes consolidated into a con-

* I have here to acknowledge my obligations to Professor Viviani, and Dr. Sasso, who called my attention to these phenomena when I visited Genoa in Jan. 1829.

glomerate. Dr. Sasso has collected about 200 species of shells from these beds; and it appears, by his catalogue, that they agree, for the most part, with the northern Subapennine fossils, more than half of them belonging to recent species.*

Nice. — At Nice the tertiary strata are upraised to a much greater height, but they may still be said to lie at the base of the Alps which tower above them. Here, also, they consist principally of blue marl and yellow sand, which appear to have been deposited in submarine valleys previously existing in the inclined secondary strata. In one district, a few miles to the west of Nice, the tertiary beds are almost exclusively composed of conglomerate, from the point of their junction with the secondary strata to the sea.

The river Magnan flows in a deep valley, which terminates at its upper extremity in a narrow ravine. Nearly vertical precipices are laid open on each side, varying from 200 to 600 feet in height, and composed of inclined beds of shingle, sometimes separated by layers of sand, and more rarely by blue micaceous marl. The pebbles in these stratified shingles agree in composition with those now brought down from the Alps by the Var and other rivers on this coast.

The dip of these strata is remarkably uniform, being always southwards, or towards the Mediterranean, at an angle of about 25°. I examined this section in company with Mr. Murchison in the summer of 1828, when the bed of the river was dried up. The geologist has then a good opportunity of examining a section of the strata, as the channel crosses for many miles the line of bearing of the beds, which may be

* Giornale Ligustico, Genoa, 1827.

traced to the base of Monte Calvo, a distance of about nine miles in a straight line from the Mediterranean. It is usually impossible to determine the exact age of such accumulations of sand and gravel, in consequence of the total absence of organic remains. Their non-existence may depend chiefly on the disturbed state of the waters, where great beds of shingle are formed, which are known to prevent testacea and fishes from living in Alpine torrents; partly on the total destruction of shells by the same friction which rounded the pebbles; and partly on the permeability of the matrix to water, which may carry away the elements of the decomposing fossil body, without substituting any other substance in their place which might retain a cast of their form.

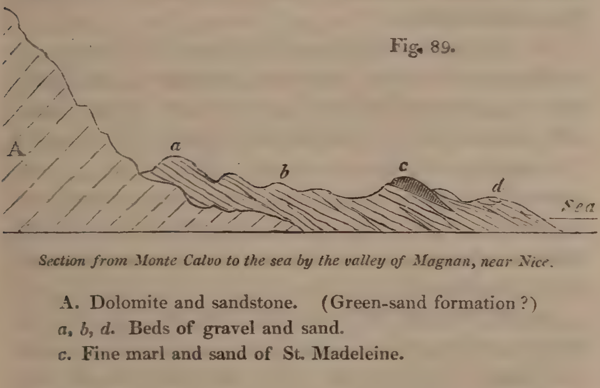
But it fortunately happens, in this instance, that in some few seams of loamy marl, intervening between the pebble-beds, and near the middle of the section, shells have been preserved in a very perfect state; and these may furnish a zoological date to the whole mass. The principal of these interstratified masses of loam occurs near the church of St. Madeleine (at *c*, diagram No. 93.), where the active researches of M. Risso have brought to light a great number of shells which agree perfectly with the species found in much greater abundance at a spot called La Trinità, and some other places nearer Nice. From these fossils it clearly appears that the formation belongs to the Older Pliocene era.

Such alternations of gravel with the usual thin layers of fine sediment may easily be explained, if we reflect that the rivers now flowing from the Maritime Alps are nearly dried up in summer, and have only strength to drift along fine mud to the sea; whereas

in winter, or on the melting of the snow, they roll along large quantities of pebbles. The thicker masses of loam, such as that of St. Madeleine, may have been produced during a longer interval, when the river shifted for a time the direction of its principal channel of discharge; so that nothing but fine mud was for a series of years conveyed to that point in the bed of the sea opposite the delta.

Monte Calvo.

Fig. 89.



Section from Monte Calvo to the sea by the valley of Magnan, near Nice.

A. Dolomite and sandstone. (Green-sand formation ?)
a, *b*, *d*. Beds of gravel and sand.
c. Fine marl and sand of St. Madeleine.

Uniform and continuous as the strata appear, on a general view, in the ravine of the Magnan, we discover, if we attempt to trace any one of them for some distance, that they thin out and are wedge-shaped. We believe that they were thrown down originally upon a steep slanting bank or talus, which advanced gradually from the base of Monte Calvo to the sea. The distance between these points is, as before mentioned, about nine miles; so that the accumulation of superimposed strata would be a great many miles in thickness, if they were placed horizontally upon one another.

The strata nearest to Monte Calvo, which may be expressed by *a*, are certainly older than those at *b*, and the group *b* was formed before *c*. The aggregate thickness, in any one place, cannot be proved to amount to 1000 feet, although it may, perhaps, be much greater. But it may never exceed 3000 or 4000 feet; whereas, if we did not suppose that the beds were originally deposited in an inclined position, we should be forced to imagine that a sea, many miles in depth, had been filled up by horizontal strata of pebbles thrown down one upon another.

At no great distance on this coast the Var is annually seen to sweep down into the sea a large quantity of gravel, which may be spread out by the waves and currents over a considerable space. The sea at the mouth of this river is now shallow, but it may originally have been 3000 feet deep, as it is now close to the shore at Nice. Here, therefore, a formation resembling that of the Magnan above described may be in progress.

In confirmation of the above reasoning, I may refer to the modern delta of the river Kander in the Lake of Thun in Switzerland. The Kander formerly ran parallel to that lake, until it was artificially turned into it about the year 1713, when the government of Berne caused two parallel subterranean galleries or tunnels to be excavated through the land which separated the course of the river from the lake; a distance of nearly a mile. The Kander, on being admitted, shot with the violence of a Swiss torrent through the tunnels, burst the arches of the galleries, and formed a ravine, which is now open to the day, about fifty feet in depth. A large quantity of mud and rock was swept into the lake, and an alluvial tract was formed

of a semicircular shape, which now extends for a mile along the original shore, and projects about a quarter of that distance into the lake. Its annual advance is said to amount to several yards*, and the delta terminates in a talus, the slope of which is inclined at an angle varying between 30° and 40°. For this fact I am indebted to the observations of Lord Cole and Mr. Egerton, who at my request measured the dip in 1833.† It follows, therefore, that the strata have successively accumulated on a plane thus highly inclined; so that, if the Lake of Thun, which is 600 feet deep‡, beyond the recently formed shoal, were drained, a vertical section might be laid open, 600 feet in height, in which strata would be seen having a greater dip than those of the Magnan, yet which had remained undisturbed from the period of their original deposition.

Tertiary Strata at the eastern extremity of the Pyrenees. — I shall conclude this chapter with one more example, derived from a region not far distant. On the borders of the Mediterranean, at the eastern extremity of the Pyrenees, in the south of France, a considerable thickness of tertiary strata is seen in the valleys of the rivers Tech, Tet, and Gly. They bear much resemblance to those already described, consisting partly of a large proportion of conglomerate, and partly of clay and sand, with subordinate beds of lignite. They abut against the primary formation of the Pyrenees, which here consists of mica-schist. Between Ceret and Boulon these tertiary strata are seen inclined at an angle of between 20° and 30°.

* See a paper by the Rev. J. Yates, on Alluvium, Ed. New Phil. Journ. 1834.

† Proceedings of Geol. Soc. 1834.

‡ Mr. Yates, ibid.

The shells which I procured from several localities were recognized by M. Deshayes as agreeing with Subapennine fossils.

Spain — Morea. — It appears, from the recent observations of Colonel Silvertop, that marine strata of the Older Pliocene period occur in patches at Malaga, and in Granada, in Spain. They have also been discovered by MM. Boblaye and Virlet in the Morea.

CHAPTER XIII.

OLDER PLIOCENE FORMATIONS — CRAG.

Crag of Norfolk and Suffolk — Appears by its fossil contents to belong to the Older Pliocene period. — Divisible into coralline and red crag. — Superincumbent lacustrine deposits — Forms of stratification (p. 91.) — Oblique layers — Cause of this arrangement — Dislocations in the crag produced by subterranean movements — Protruded masses of chalk (p. 98.) — Associated alluvium.

The Older Pliocene strata, described in the last chapter, are all situated in countries bordering the Mediterranean; but there is a group in our own island, probably belonging to the same era, which I shall now consider. I have already alluded to this deposit under the provincial name of crag*, and pointed out its superposition to the London clay, a tertiary formation of much higher antiquity.† The crag is chiefly developed in the eastern parts of Norfolk and Suffolk, from whence it extends into Essex.

Its relative age. — A collection of the shells of the "crag" beds, which I formed in 1829, together with a much larger number sent me by my friend Mr. Mantell, of Lewes, were carefully examined by M. Deshayes, and compared with the tertiary species in his cabinet. This comparison gave the following re-

* Vol. III. p. 358. † See Fig. 64. Vol. III. p. 360.

sult: — out of 111 species, 66 were extinct or unknown, and 45 recent; the last, with one exception (*Voluta Lamberti*, Sow.), being now inhabitants of the German Ocean. Such being the proportion of recent and extinct species, I referred the crag, in accordance with the rules above laid down, to the Older Pliocene period.* Since that time a much larger number of organic remains has been obtained from this formation by several naturalists, especially by Mr. Wood, of Hasketon, in Suffolk; but the species have not yet been compared with those of other tertiary strata, so as to enable me to announce the general bearing of the results.

It appears, however, from a recent communication made by Mr. Charlesworth, of Suffolk, to the Geological Society, that the inferior and fossiliferous portion of the crag is divisible into two distinct masses, one of which may be termed the lower or "coralline crag," and the other the "red crag." The lower division is composed of calcareous sand, chiefly derived from decomposed corals, in which are imbedded shells, corals, and sponges, in a good state of preservation, and which must evidently have lived on the spot.

This coralline formation is almost without stratification, and in some places forms a soft stone used in building; it has not been seen to attain a greater thickness than about 12 feet, but it was not pierced through at that depth in all localities. The coralline crag rests immediately on the London clay, and may be studied at several places in Suffolk, as at Tattingstone, Ramsholt, Sudburn Park, Orford, and Aldborough.

The red crag is distinguished from the coralline, upon which it lies in some places unconformably, by

* See Vol. III. p. 391.

the deep red ferruginous or ochreous colour of its sands and fossils. It consists in great part of numerous layers of siliceous sand containing shells, which are usually broken and worn. Among these are many of the genera Buccinum and Murex, which have never been met with in the coralline crag.

Mr. Wood states that he has in his collection, exclusive of Polypi, Radiaria, and Crustacea, no less than 450 species of invertebrated animals from the crag, among which there are of annulata 13, cirrhipeda 11, conchifera 189, mollusca 257. Among the mollusca are 50 species of minute cephalopoda, of the order Forammifera of D'Orbigny, which seem peculiar to the coralline crag. In the red crag have been found 235 species of the above classes of fossils; in the coralline crag 353; about 150 species being common to the two divisions.

It must remain for future investigations to determine how far this great addition of new fossils may modify the proportional number of recent to extinct shells previously deduced from more limited data.* The greater part of the shells before examined were derived from the red crag, which is evidently a newer deposit than the coralline, although I do not anticipate that these formations will turn out to be referrible to distinct periods, as they contain so many species in common. The generic difference in the shells and other organic forms may depend on a difference of conditions, such as might exist in different parts of the sea at one and the same period. Thus we may suppose one region, where the water is deep and tranquil, to be favourable to the growth of corals, sponges, echini, and microscopic cephalopods, such as charac-

* See the note at the end of this chapter.

terize the lower crag; whilst in another and somewhat shallower region, where currents prevailed, and to which sand and shingle were often drifted, no zoophytes might exist, although certain kinds of testacea abounded. According to this hypothesis, it is conceivable that a certain space where the coralline crag was first formed became afterwards converted into a shoal, or exposed to the action of waves and currents, and was then the receptacle of deposits like the fossiliferous red crag.

The shelly beds of Norfolk appear to belong exclusively to the red crag; but on the northern limits of that county they are said to be occasionally covered by a still newer stratum, containing exclusively species now living in the adjoining sea. This is doubtless the marine formation described by Mr. Phillips as occurring throughout Holderness, in Yorkshire.* According to this view, the succession of tertiary formations, in following our eastern coast from the estuary of the Thames to that of the Humber, will be, first, in Essex, the Eocene or London clay; secondly, in Suffolk, the coralline crag, probably belonging to the Older Pliocene period; next, the red crag of Suffolk and Norfolk, also of the Older Pliocene era; and lastly, on the extreme northern boundary of Norfolk and in Holderness, a marine Newer Pliocene deposit.

Among the teeth of fish from the crag, Mr. Agassiz informs me that he has recognized many belonging to the genus Platax, a form now foreign to our northern seas, and occurring in the Indian Ocean.

The strata which occupy the larger part of the cliffs of Norfolk and Suffolk are for the most part

* See Phillips's Geol. of Yorksh.

superimposed upon the above-mentioned fossiliferous strata, and are very heterogeneous in their mineral character, consisting of sand, gravel, and blue or brown marl; the shells imbedded in the sand and marl being broken, and sometimes finely comminuted. In many places are seen alternations of sand and shingle, destitute of organic remains, and more than two hundred feet in thickness, as in the Suffolk cliffs, between Dunwich and Yarmouth. In others, we meet with an enormous mass, more than three hundred feet in thickness, of sand, loam, and clay, containing bones of terrestrial quadrupeds, and drift wood; sometimes stratified regularly, at others consisting of a confused heap of rubbish, in which fragments of the chalk and its flints are imbedded in a chalky marl.

In this aggregate are also found many fragments of older rocks, the septaria of the London clay, together with ammonites, vertebræ of ichthyosauri, and other fossils from parts of the oolitic series. It has been questioned whether all the above-mentioned beds can be considered as belonging to the same era, and the subject certainly admits of doubt; but after examining, in 1829, the whole line of coast of Essex, Suffolk, and Norfolk, I found it impossible to draw any line of separation between the different groups. Each seemed in its turn to pass into another; and those masses which approach in character to alluvium, and contain the remains of terrestrial quadrupeds, are occasionally intermixed with the strata of the crag.

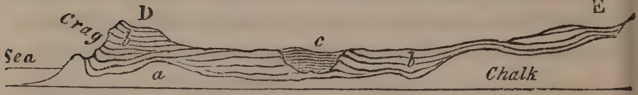
There are, however, lacustrine deposits overlying the crag, which no doubt belong to a distinct zoological period. These are found in small cavities, which must have existed on the surface of the crag after its

elevation, and which formed small lakes or ponds wherein recent fresh-water testacea were included in loamy strata. (See Fig. 94. *c.*)

Relative position. — The crag is seen to rest on the chalk and on the London clay, but more commonly on the chalk. The strata are in great part horizontal, or slightly undulating; but at some points they are much disturbed, especially where several masses of chalk appear to have been protruded from below.

The annexed section may give a general idea of

Fig. 94.



a. Chalk. *b.* Crag. *c.* Lacustrine deposit.
D. Trimmingham beacon.
E. Interior and higher part of Norfolk. *

the manner in which the crag may be supposed to rest on the chalk as we pass from the Norfolk cliffs, at Trimmingham, into the interior, where the country rises gradually.

The outline of the surface of the subjacent chalk, in this section, is imaginary, but is such as might explain the relations of those protruded masses, three of which appear in the cliffs near Trimmingham, and which some geologists have too hastily assumed to be unconnected with the great mass of chalk below. I shall treat of these presently, when describing the

* This section is compiled principally from one by Mr. Murchison; the others in this chapter are from sketches which I made in 1829.

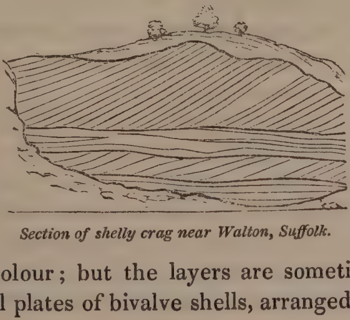
disturbances which the crag appears to have suffered since its original deposition.

In the interior, at E, there is a thick covering of sand and gravel upon the chalk, having the characters of an alluvium, partly, perhaps, marine, and partly terrestrial, and which seems to pass gradually in this district into the regular marine strata of the crag.

Forms of stratification. — In almost every formation the individual strata are rarely persistent for a great distance, the superior and inferior planes being seldom precisely parallel to each other; and if the materials are very coarse, the beds often thin out if we trace them for a few hundred yards. There are also many cases where all the layers are oblique to the general direction of the strata, and the crag affords most interesting illustrations of this phenomenon.

In the sea-cliff near Walton, in Suffolk, opposite the Martello Tower, called R, the section represented in the annexed diagram is seen. The vertical height is about 20 feet, and the beds consist alternately of sets of inclined and horizontal layers of sand and comminuted shells. The sand is siliceous, and of a fer-

Fig. 95.



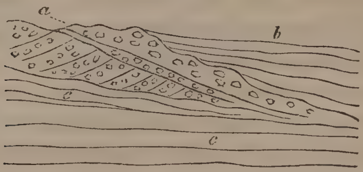
Section of shelly crag near Walton, Suffolk.

ruginous colour; but the layers are sometimes made up of small plates of bivalve shells, arranged with their

flat sides parallel to the plane of each layer, like mica in micaceous sandstones.

The number of laminæ in the thickness of an inch, both in the siliceous and shelly sand, varies from seven to ten, so that it is impossible to express them all in the diagram. The height of the uppermost stratum is, in this instance, remarkable, as it extends to twelve feet. The inclination of the laminæ is about 30°; but in the cliffs of Bawdesey, to the eastward, they are sometimes inclined at an angle of 45°, and even more.

Fig. 96.



Section at the lighthouse near Happisborough. Height sixteen feet.

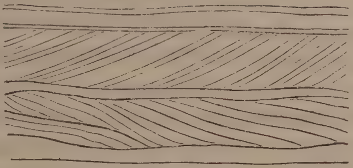
a. Pebbles of chalk flint, and of rolled pieces of white chalk.
b. Loam overlying *a.* *c, c.* Blue and brown clay.

This diagonal arrangement of the layers, sometimes called "*false* stratification," is not confined to deposits of fine sand and comminuted shells; for we find beds of shingle disposed in the same manner, as is seen in the annexed section (Fig. 96.).

The direction of the dip of the inclined layers, throughout the Suffolk coast, is so uniformly to the south, that I only saw two or three instances of a contrary nature, where the inclination was northerly. One of the best examples of this variation is exhibited in a cliff between Mismer and Dunwich (Fig. 97.) In this case, there are about six layers in the thick-

ness of an inch, and the part of the cliff represented is about six feet high.

Fig. 97.



Section of part of Little Cat cliff, composed of quartzose sand, showing the inclination of the layers in opposite directions.

Another example may be seen near Walton, where the layers, which are of extreme tenuity, consist of ferruginous sand, brown loam, and comminuted shells. It is not uncommon to find in this manner sets of perfectly horizontal strata resting upon and covered by groups of wavy and transverse layers.

Fig. 98.

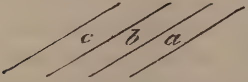
Lamination of shelly sand and loam, near the Signal-house, Walton. Vertical height four feet.

The appearances exhibited in the diagrams are not peculiar to the crag: they may be found in almost every gravel-pit; and I have seen sand and pebble-beds of all ages, including the old red sandstone, greywacké, and clay-slate, exhibit the same arrangement.

If we now inquire into the causes of such a disposition of the materials of each bed or group of layers, it

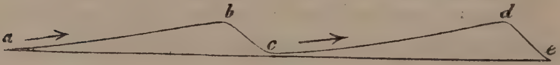
may, in the first place, be remarked, that however numerous may be the successive layers *a*, *b*, *c*, the layer *a* must have been deposited before *b*, *b* before *c*, and so of the rest.

Fig. 99.



We must suppose that each thin seam was thrown down on a slope, and that it conformed itself to the side of the steep bank, just as we see the materials of a talus arrange themselves at the foot of a cliff when they have been cast down successively from above. If the transverse layers are cut off by a nearly horizontal line, as in many of the above sections, it may arise from the denuding action of a wave which has carried away the upper portion of a submarine bank, and truncated the layers of which it was composed. But I do not conceive this hypothesis to be necessary; for if a bank have a steep side, it may grow by the successive apposition of thin strata thrown down upon its slanting side, and the removal of matter from the top may proceed simultaneously with its lateral extension. The same current may borrow from the top what it gives to the sides; a mode of formation which I had lately an opportunity of observing on the rippled surface of the hills of blown sand near Calais. The undulating ridges and intervening furrows on the dunes of blown sand resembled exactly in form those caused by the waves on a sea-beach, and were always at right angles to the direction of the wind which had produced them. Each ridge had one side slightly inclined, and

Fig. 100.



the other steep; the lee side being always steep, as *b, c, d, e;* the windward side a gentle slope, as *a, b, c, d*. When a gust of wind blew with sufficient force to drive along a cloud of sand, all the ridges were seen to be in motion at once, each encroaching on the furrow before it, and, in the course of a few minutes, filling the place which the furrows had occupied. Many grains of sand were drifted along the slopes *a b* and *c d*, which, when they fell over the scarps *b c* and *d e*, were under shelter from the wind; so that they remained stationary, resting, according to their shape and momentum, on different parts of the descent. In this manner each ridge was distinctly seen to move slowly on as often as the force of the wind augmented. We shall not strain analogy too far, by supposing that, in such cases, the same laws may govern subaqueous and subaërial phenomena; and if so, we may imagine a submarine bank to be nothing more than one of the ridges of ripple on a larger scale, which may increase in the manner before suggested, by successive additions to the steep scarps.

The set of tides and currents, in opposite directions, may account for sudden variations in the direction of the dip of the layers, as represented in Fig. 97.; while the general prevalence of a southerly inclination in the crag of Suffolk may indicate that the matter was brought by a current from the north.

I may refer to a drawing given in the first volume*, to show the analogy of the arrangement of the submarine strata, just considered, to that exhibited by deposits formed in the channels of rivers where a considerable transportation of sediment is in progress.

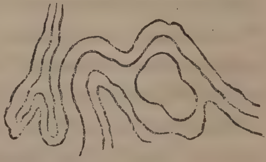
* P. 374. Fig. 10.

Derangement in the crag strata.—In the above examples I have explained the want of parallelism or horizontality in the subordinate layers of different strata, by reference to the mode of their original deposition; but there are signs of disturbance which can only be accounted for by subsequent movements. The same blue and brown clay, or loam, which is often perfectly horizontal, and as regularly bedded as any of our older formations, is, in other places, curved and even folded back upon itself, in the manner represented in the annexed diagrams.

Fig. 101.

Bent strata of loam in the cliffs between Cromer and Runton.

Fig. 102.



Folding of the strata between East and West Runton.

In the last of these cuts a central nucleus of sand is surrounded by argillaceous and sandy layers. This phenomenon is very frequent; and there are instances where the materials thus enveloped consist of broken flints mingled with pieces of chalk, forming a white mass, encircled by dark laminated clay. The diameter of these included masses, as seen in sections laid open in the sea cliffs, varies from five to fifteen feet.

East of Sherringham, a heap of partially-rounded flints, about five feet in diameter, is nearly enveloped by finely laminated strata of sand and loam, and some of the loam is entangled in the midst of the flints.

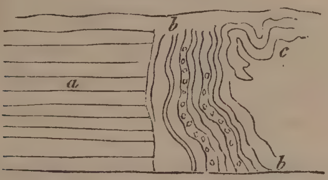
Fig. 103.

Section in the Cliffs east of Sherringham.
a. Sand and loam in thin layers.

In this and similar instances, we may imagine the yielding strata, *a*, to have subsided into a cavity, and the flints belonging to a superincumbent bed to have pressed down with their weight, so as to cause the strata to fold round them.

That some masses of stratified sand and loam have actually sunk down into cavities, or have fallen like landslips into ravines, seems indicated by other appearances. Thus, near Sherringham, the argillaceous beds, *a*, represented in the annexed diagram (Fig. 104.), are cut off abruptly, and succeeded by the vertical and contorted series *b, c*. The face of the cliff here repre-

Fig. 104.



Section east of Sherringham, Norfolk.

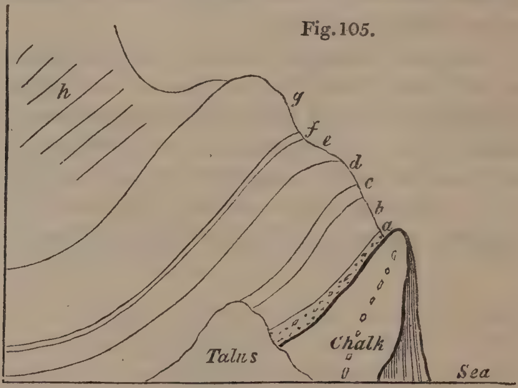
a. Sand, loam, and blue clay. *b, b.* Sand and gravel.
c. Twisted beds of loam.

sented is twenty-four feet in height. Some of the layers in *b, b* are composed of pebbles, and these alternate

with thin beds of loose sand. The whole set must once have been horizontal, and must have moved in a mass, or the relative position of the several parts would not have been preserved. Similar appearances may, perhaps, be produced when chasms open during earthquakes, and portions of yielding strata fall in from above and are engulphed.

Protruded masses of chalk. — But whatever opinion we may entertain on this point, we cannot doubt that subterranean movements have given rise to some of the local derangements of this formation, particularly where masses of solid chalk pierce, as it were, through

Fig. 105.



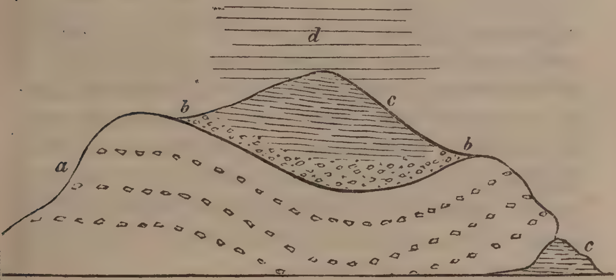
Side view of a promontory of chalk and crag, Trimmingham, Norfolk.

a. Gravel and ferruginous sand, rounded and angular pieces of chalk flint, with some quartz pebbles, 3 feet.
b. Laminated blue clay, 8 feet.
c. Yellow sand, 1 foot 6 inches.
d. Dark blue clay, with fragments of marine shells, 6 feet.
e. Yellow loam and flint gravel, 3 feet.
f. Light blue clay, 1 foot. *g.* Sand and loam, 12 feet.
h. Yellow and white sand, loam, and gravel, about 100 feet.

the crag. Thus, between Mundesley and Trimmingham we see the appearances exhibited in the accompanying view (Fig. 105.). The chalk, of which the strata are highly inclined, or vertical, projects in a promontory, because it offers more resistance to the action of the waves than the tertiary beds which, on both sides, constitute the whole of the cliff. The height of the soft crag strata immediately above the chalk is, in this place about 130 feet. Those which are in contact (see the wood-cut) are inclined at an angle of 45°, and appear more disturbed than in other parts of the cliffs, as if they had been displaced by the movement by which the chalk was protruded.

Very similar appearances are exhibited by the northernmost of the three protuberances of chalk, of which a front view is given in the annexed diagram. It oc-

Fig. 106.



Northern protuberance of chalk, Trimmingham.

a. Chalk with flints.
b. Gravel of broken and half-rounded flints.
c. Laminated blue clay. *d.* Sand and yellow loam.

cupies a space of about one hundred yards along the shore, and projects about sixty yards in advance of the general line of cliff. One of its edges, at *c*, rests upon

the blue clay beds of the crag, in such a manner as to imply that the mass had been undermined when the crag was deposited, unless we suppose, as some have done, that this chalk is a great detached mass enveloped by crag. For, as one of the "Needles," or insulated rocks of chalk, which stood 120 feet above high water mark, at the western extremity of the Isle of Wight, fell into the sea in 1772 *, so a pinnacle of chalk may have been precipitated into the tertiary sea, at a point where some strata of the crag had previously accumulated. The beds of flint and chalk in the above diagram appear nearly horizontal; but they are in fact highly inclined inwards towards the cliff. The rapid waste of the Norfolk coast might soon enable us to understand the true position of this mass, if observations and drawings were made from time to time of the appearances which it presents. †

Perhaps it may be necessary to suppose, that subterranean movements were in progress during the deposition of the crag; and the extraordinary dislocations of the beds, in some places, which in others are perfectly regular and horizontal, may be most easily accounted for by introducing an alternate rise and depression of the bed of the sea, such as we know to be usually attendant on a series of subterranean convulsions. Several of the contortions may also have been produced by lateral movements.

Passage of marine crag into alluvium. — By supposing the adjoining lands to have participated in this movement, we may explain the origin of those masses

* Dodsley's Annual Register, vol. xv. p. 140.

† For additional facts respecting the sections and organic remains of part of the coast above described, see Geology of Norfolk, by Samuel Woodward, 1833.

of an alluvial character which contain the detritus of many rocks, the bones of land animals, and of drift timber, which were evidently swept down into the sea. The land-floods which accompany earthquakes are, as we have seen, capable of transporting such materials to great distances; and, as part of these alluviums must be left somewhere upon the land, we may expect to find, on exploring the submarine surface when it is afterwards disclosed, a gradual passage from the terrestrial alluvium to that which was carried down into the sea, so as to alternate with marine beds.*

* While this sheet was passing through the press I received a letter from the Rev. Dr. Fleming, author of Brit. Anim.; to which I shall allude, because some imagine that the "crag" will be found to contain a larger proportion of recent species than I had formerly inferred. Dr. F. rather anticipates the contrary, for among the crag fossils examined by him he recognizes a decided plurality of species now living in the German Ocean. Thus among a small number of minute multilocular cephalopods of the crag he has seen Nautilus crispus, Rotalia beccaria, R. beccarii-perversa, Lobatula vulgaris (the sinistral var.), and Vermiculum oblongum. Out of a few zoophytes of the crag sent to him some were extinct, but he found the following recent species: Eschara retiformis, E. fascialis, Retepora reticulata, with Hornera frondiculala of Lamouroux (a Mediterranean species), Cellepora pumicosa, Berenicea utriculata, Farcimia fistulosa, Caryophyllia cyathus, and C. ramea.

CHAPTER XIV.

VOLCANIC ROCKS OF THE OLDER PLIOCENE PERIOD.

Igneous rocks of this period in Italy — Volcanic region of Olot, in Catalonia — Lava currents — Ravines — Ancient alluvium — Jets of air called "Bufadors" (p. 111.) — Age of the Catalonian volcanos uncertain — Earthquake of Olot in 1421 — Sardinian volcanos — District of the Eifel and Lower Rhine — Peculiar characteristics of the Eifel volcanos — Lake craters (p. 115.) — Trass — Age of the Eifel volcanic rocks uncertain (p. 122.) — Brown coal formation.

Italy.—It is part of my proposed plan to consider the igneous as well as the aqueous formations of each period; but I am far from being able as yet to assign to each of the numerous groups of volcanic origin scattered over Europe a precise place in the chronological series. It has been already stated, that the volcanic rocks of Tuscany belong, in part at least, to the Older Pliocene period, — those, for example, of Radicofani, Viterbo, and Aquapendente, which have been chiefly erupted beneath the sea. The same observation would probably hold true in regard to the igneous rocks of the Campagna di Roma.

But several other districts, of which the dates are still uncertain, may be mentioned in this chapter as being possibly referrible to the period now under consideration. It will at least be useful to explain the points which require elucidation before the exact age of the groups about to be described can be accurately determined.

1. St Michel. 2. Monte Oliveto. 3. Montsacopa. 4. Puig Sacourona. 5. Garrinada

View of the Volcanoes around Olot in Catalonia.

1 Primary and secondary rocks of Pyrenees. 2 Secondary formations. 3 Volcanic Rocks.

Volcanos of Olot, in Catalonia.—I shall first describe a district of extinct volcanos in the north of Spain, which is little known, and which I visited in the summer of 1830.

The whole extent of country occupied by volcanic products in Catalonia is not more than fifteen geographical miles from north to south, and about six from east to west. The vents of eruption range entirely within a narrow band running north and south; and the branches, which are represented as extending

Fig. 107.

Volcanic district of Catalonia.

eastward in the map, are formed simply of two lava-streams — those of Castell Follit and Cellent.

Dr. Maclure, the American geologist, was the first who made known the existence of these volcanos *; and, according to his description, the volcanic region extended over twenty square leagues, from Amer to Massanet. I searched in vain in the environs of Massanet, in the Pyrenees, for traces of a lava-current; and I can say, with confidence, that the adjoined map gives a correct view of the true area of the volcanic action.

Geological structure of the district. — The eruptions have burst entirely through secondary rocks, composed in great part of grey and greenish sandstone and conglomerate, with some thick beds of nummulitic limestone. The conglomerate contains pebbles of quartz, limestone, and Lydian stone. The limestone is not only replete with nummulites, but occasionally includes oysters, pectens, and other shells. This system of rocks is very extensively spread throughout Catalonia; one of its members being a red sandstone, to which the celebrated salt-rock of Cardona is subordinate. It is conjectured that the whole belongs to the age of our green-sand and chalk.

Near Amer, in the Valley of the Ter, on the southern borders of the region delineated in the map, primary rocks are seen consisting of gneiss, mica-schist, and clay-slate. They run in a line nearly parallel to the Pyrenees, and throw off the secondary strata from their flanks, causing them to dip to the north and north-west. This dip, which is towards the Pyrenees, is connected with a distinct axis of elevation, and pre-

* Maclure, Journ. de Phys., vol. lxvi. p. 219., 1808; cited by Daubeny, Description of Volcanos, p. 24.

vails through the whole area described in the map, the inclination of the beds being sometimes at an angle of between 40 and 50 degrees.

It is evident that the physical geography of the country has undergone no material change since the commencement of the era of the volcanic eruptions, except such as has resulted from the introduction of new hills of scoriæ, and currents of lava upon the surface. If the lavas could be remelted and poured out again from their respective craters, they would descend the same valleys in which they are now seen, and re-occupy the spaces which they at present fill. The only difference in the external configuration of the fresh lavas would consist in this, that they would nowhere be intersected by ravines, or exhibit marks of erosion by running water.

Volcanic cones and lavas. — There are about fourteen distinct cones with craters in this part of Spain, besides several points whence lavas may have issued; all of them arranged along a narrow line running north and south, as will be seen in the map. The greatest number of perfect cones are in the immediate neighbourhood of Olot, some of which are represented in the annexed plate (Pl. XI.); and the level plain on which that town stands has clearly been produced by the flowing down of many lava-streams from those hills into the bottom of a valley, probably once of considerable depth, like those of the surrounding country.

In this Plate an attempt is made to represent by colours the different geological formations of which the country is composed.* The blue line of moun-

* This view is taken from a sketch which I made on the spot in 1830.

tains in the distance are the Pyrenees, which are to the north of the spectator, and consist of primary and ancient secondary rocks. In front of these are the secondary formations described in this chapter, coloured grey. Different shades of this colour are introduced, to express various distances. The flank of the hill, in the foreground, called Costa de Pujou, is composed partly of secondary rocks, and partly of volcanic, the red colour expressing lava and scoriæ.

The Fluvia, which flows near the town of Olot, has cut to the depth of only 40 feet through the lavas of the plain before mentioned. The bed of the river is hard basalt; and at the bridge of Santa Madalena are seen two distinct lava-currents, one above the other, separated by a horizontal bed of scoriæ eight feet thick.

In one place, to the south of Olot, the even surface of the plain is broken by a mound of lava, called the "Bosque de Tosca," the upper part of which is scoriaceous, and covered with enormous heaps of fragments of basalt more or less porous. Between the numerous hummocks thus formed are deep cavities, having the appearance of small craters. The whole precisely resembles some of the modern currents of Etna, or that of Côme, near Clermont; the last of which, like the Bosque de Tosca, supports only a scanty vegetation.

Most of the Catalonian volcanos are as entire as those in the neighbourhood of Naples, or on the flanks of Etna. One of these, figured in the plate, called Montsacopa, is of a very regular form, and has a circular depression or crater at the summit. It is chiefly made up of red scoriæ, undistinguishable from that of the minor cones of Etna. The neighbouring hills of Olivet and Garrinada, also figured in the plate, are of

similar composition and shape. The largest crater of the whole district occurs farther to the east of Olot, and is called Santa Margarita. It is 455 feet deep, and about a mile in circumference. Like Astroni, near Naples, it is richly covered with wood, wherein game of various kinds abounds.

Although the volcanos of Catalonia have broken out through sandstone, shale, and limestone, as have those of the Eifel, in Germany, to be described in the sequel, there is a remarkable difference in the nature of the ejections composing the cones in these two regions. In the Eifel, the quantity of pieces of sandstone and shale thrown out from the vents is often so immense as far to exceed in volume the scoriæ, pumice, and lava; but I sought in vain in the cones near Olot for a single fragment of any extraneous rock; and Don Francisco Bolos, an eminent botanist of Olot, informs me that he has never been able to detect any. Volcanic sand and ashes are not confined to the cones, but have been sometimes scattered by the wind over the country, and drifted into narrow valleys, as is seen between Olot and Cellent, where the annexed section is exposed. The light cindery volcanic matter rests in thin regular layers, just as it alighted on the slope formed by the solid conglomerate. No flood could

Fig. 108.

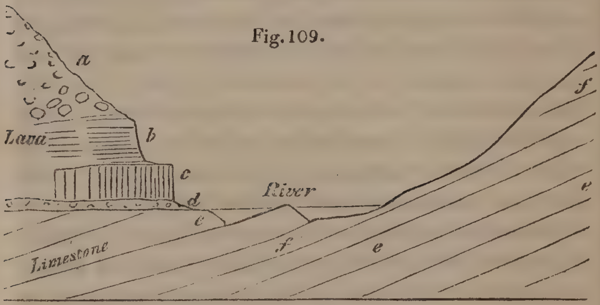
a. Secondary conglomerate.
b. Thin seams of volcanic sand and scoriæ.

have passed through the valley since the scoriæ fell, or these would have been for the most part removed.

The currents of lava in Catalonia, like those of

Auvergne, the Vivarais, Iceland, and all mountainous countries, are of considerable depth in narrow defiles, but spread out into comparatively thin sheets in places where the valleys widen. If a river has flowed on nearly level ground, as in the great plain near Olot, the water has only excavated a channel of slight depth; but where the declivity is great, the stream has cut a deep section, sometimes by penetrating directly through the central part of a lava-current, but more frequently by passing between the lava and the secondary rock which bounds the valley. Thus, in the accompanying section, at the bridge of Cellent, six miles east of Olot,

Fig. 109.



Section above the bridge of Cellent.

a. Scoriaceous lava.
b. Schistose basalt.
c. Columnar basalt.
d. Scoriæ, vegetable soil, and alluvium.
e. Nummulitic limestone.
f. Micaceous grey sandstone.

we see the lava on one side of the small stream; while the inclined stratified rocks constitute the channel and opposite bank. The upper part of the lava at that place, as is usual in the currents of Etna and Vesuvius, is scoriaceous; farther down it becomes less porous, and assumes a spheroidal structure; still lower it divides in horizontal plates, each about two inches in

thickness, and is more compact. Lastly, at the bottom is a mass of prismatic basalt about five feet thick. The vertical columns often rest immediately on the subjacent secondary rocks; but there is sometimes an intervention of such sand and scoriæ as cover the country during volcanic eruptions, and which when unprotected, as here, by superincumbent lava, is washed away from the surface of the land. Sometimes, the bed *d* contains a few pebbles and angular fragments of rock; in other places fine earth, which may have constituted an ancient vegetable soil.

In several localities, beds of sand and ashes are interposed between the lava and subjacent stratified rock, as may be seen if we follow the course of the lava-current which descends from Las Planas towards Amer, and stops two miles short of that town. The river there has often cut through the lava, and through eighteen feet of underlying limestone. Occasionally an alluvium, several feet thick, is interspersed between the igneous and marine formation; and it is interesting to remark that in this, as in other beds of pebbles occupying a similar position, there are no rounded fragments of lava; whereas, in the most modern gravel-beds of rivers of this country, volcanic pebbles are abundant.

The deepest excavation made by a river through lava, which I observed in this part of Spain, is that seen in the bottom of a valley near San Feliu de Palleróls, opposite the Castell de Stolles. The lava there has filled up the bottom of a valley, and a narrow ravine has been cut through it to the depth of one hundred feet. In the lower part the lava has a columnar structure. A great number of ages were probably required for the erosion of so deep a ravine;

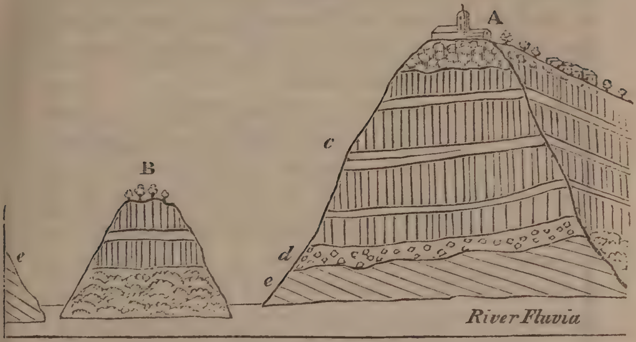
but we have no reason to infer that this current is of higher antiquity than those of the plain near Olot. The fall of the ground, and consequent velocity of the stream, being in this case greater, a more considerable volume of rock may have been removed in the same time.

I shall describe one more section to elucidate the phenomena of this district. A lava-stream, flowing from a ridge of hills on the east of Olot, descends a considerable slope, until it reaches the valley of the river Fluvia. Here, for the first time, it comes in contact with running water, which has removed a portion, and laid open its internal structure in a precipice about 130 feet in height, at the edge of which stands the town of Castell Follit.

By the junction of the rivers Fluvia and Teronel the mass of lava has been cut away on two sides; and the insular rock B (Fig. 110.) has been left, which was probably never so high as the cliff A, as it may have constituted the lower part of the sloping side of the original current.

From an examination of the vertical cliffs, it appears that the upper part of the lava on which the town is built is scoriaceous, passing downwards into a spheroidal basalt; some of the huge spheroids being no less than six feet in diameter. Below this is a more compact basalt with crystals of olivine. There are in all about four distinct ranges of prismatic basalt, separated by thinner beds not columnar, and some of which are schistose. The whole mass rests on alluvium, ten or twelve feet in thickness, composed of pebbles of limestone and quartz, but without any intermixture of igneous rocks; in which circumstance alone it appears to differ from the modern gravel of the Fluvia.

Fig. 110.



Section at Castell Follit.

A. Church and town of Castell Follit, overlooking precipices of basalt.
B. Small island, on each side of which branches of the river Teronel flow to meet the Fluvia.
c. Precipice of basaltic lava, chiefly columnar, about 130 feet in height.
d. Ancient alluvium underlying the lava-current.
e. Inclined strata of secondary sandstone.

Bufadors.—The volcanic rocks near Olot have often a cavernous structure, like some of the lavas of Etna; and in many parts of the hill of Batet, in the environs of the town, the sound returned by the earth, when struck, is like that of an archway. At the base of the same hill are the mouths of several subterranean caverns, about twelve in number, which are called in the country "bufadors," from which a current of cold air issues during summer, but which in winter is said to be scarcely perceptible. I visited one of these bufadors in the beginning of August, 1830, when the heat of the season was unusually intense, and found a cold wind blowing from it; which may easily be ex-

plained; for as the external air, when rarefied by heat, ascends, the pressure of the colder and heavier air of the caverns in the interior of the mountain causes it to rush out to supply its place.

Age of the Catalonian volcanos uncertain.—It now only remains to offer some remarks on the probable age of these Spanish volcanos. Attempts have been made to prove, that in this country, as well as in Auvergne and the Eifel, the earliest inhabitants were eye-witnesses to the volcanic action. In the year 1421, it is said, when Olot was destroyed by an earthquake, an eruption broke out near Amer, and consumed the town. The researches of Don Francisco Bolos have, I think, shown, in the most satisfactory manner, that there is no good historical foundation for the latter part of this story; and any geologist who has visited Amer must be convinced that there never was any eruption on that spot. It is true, that, in the year above mentioned, the whole of Olot, with the exception of a single house, was cast down by an earthquake; one of those shocks which, at distant intervals during the last five centuries, have shaken the Pyrenees, and particularly the country between Perpignan and Olot, where the movements, at the period alluded to, were most violent.

Some houses are said to have sunk into the earth; and this account has been corroborated by the fact that, within the memory of persons now living, the buried arches of a Benedictine monastery were found at a depth of six feet beneath the surface; and still later, some houses were dug out in the street called Aigua. Don Bolos informed me, that he was present when the latter excavation was made, and when the roof of a buried house was found nearly entire; the

interior of the building being in a great part empty, so that it was necessary to fill it up with earth and stones, in order to form a sure foundation for the new edifice.

The annihilation of the ancient Olot may, perhaps, be ascribed, not to the extraordinary violence of the movement on that spot, but to the cavernous nature of the subjacent rocks; for Catalonia is beyond the line of those European earthquakes which have, within the period of history, destroyed towns throughout extensive areas.

As we have no historical records, then, to guide us in regard to the extinct volcanos, we must appeal to geological monuments. I have little doubt that some fossil land-shells, and bones of quadrupeds, will hereafter reward the industry of collectors. If such remains are found imbedded in volcanic ejections, the period of the eruptions may be inferred; but at present we have no evidence beyond that afforded by superposition, in regard to which the annexed diagram will present to the reader, in a synoptical form, the results obtained from numerous sections.

Fig. 111.

Superposition of rocks in the volcanic district of Catalonia.

a. Sandstone and nummulitic limestone.
b. Older alluvium without volcanic pebbles.
c. Cones of scoriæ and lava. *d.* Newer alluvium.

The more modern alluvium, *d*, is partial, and has been formed by the action of rivers and floods upon the

lava; whereas the older gravel, *b*, was strewed over the country before the volcanic eruptions. In neither have any organic remains been discovered; so that we can merely affirm, as yet, that the volcanos broke out after the elevation of some of the newest rocks of the secondary series, and before the formation of an alluvium, *d*, of unknown date. The integrity of the cones merely shows that the country has not been agitated by violent earthquakes, or subjected to the action of any great transient flood since their origin.

East of Olot, on the Catalonian coast, marine tertiary strata occur, which, near Barcelona, attain the height of about five hundred feet. It appears probable, from a small number of shells which I collected, that these strata may correspond with the Subapennine beds; so that if the volcanic district had extended thus far, we might be able to determine the age of the igneous products, by observing their relation to these Older Pliocene formations.*

Sardinian volcanos.—The line of extinct volcanos in Sardinia, described by Captain Smyth†, is also of uncertain date, as, notwithstanding the freshness of some of the cones and lavas, they may be of high antiquity. They rest, however, on a tertiary formation, supposed by some to correspond to the Subapennine strata, but of which the fossil remains have not been fully described.

Volcanic rocks of the Eifel.—The volcanos of the Lower Rhine and the Eifel are, for the most part, of no

* For some account of the Olot volcanos, see "Noticia de los Estinguidos Volcanes de la Villa de Olot," by Francisco Bolos. Barcelona. No date; but the observations, I am told, preceded those of Dr. Maclure.

† Present State of Sardinia, &c. pp. 69, 70.

less uncertain date than those of Catalonia; but I am desirous of pointing out some of their peculiar characters, and shall, therefore, treat of them in this chapter, trusting that future investigations will determine their chronological relations more accurately.

For the geographical details of this volcanic region the reader is referred to the annexed map (Fig. 112.), for which I am indebted to Mr. Horner, whose residence in the country has enabled him to verify the maps of MM. Noeggerath and Von Oeynhausen, from which that now given has been principally compiled.

There has been a long succession of eruptions in this country, and some of them must have occurred when its physical geography was in a very different state, while others have happened when the whole district had nearly assumed its present configuration.

The fundamental rock of the Eifel is an ancient secondary sandstone and shale, to which the obscure and vague appellation of "greywacké" has been given. The formation has precisely the characters of a great part of those gray and red sandstones and shales, which are called "old red sandstone" in England and Scotland, where they constitute the inferior member of the carboniferous series. In the Eifel they occupy the same geological position, and in some parts alternate with a limestone, containing trilobites and other fossils of our "mountain" and "transition" limestones. The strata are inclined at all angles, from the horizontal to the vertical, and must have undergone reiterated convulsions before the country was moulded into its present form.

Lake-craters.—The volcanos have broken out sometimes at the bottom of deep valleys, sometimes on the summit of hills, and frequently on intervening

Fig. 112.

English Miles.

1 2 3 4 5

Volcanic District { A. of the Upper Eifel. B. of the Lower Eifel.

Trachyte.

Points of eruption, with craters and scoriæ.

Basalt.

Brown coal.

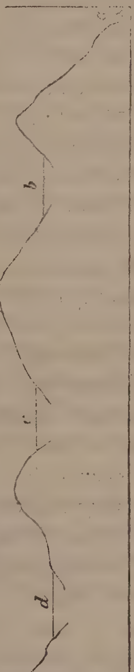
N. B. The country in that part of the map which is left blank is almost entirely composed of greywacké.

platforms. The traveller often falls upon them unexpectedly in a district otherwise extremely barren of geological interest. Thus, for example, he might arrive at the village of Gemund, immediately south of Daun, without suspecting that he was in the immediate vicinity of some of the most remarkable vents of eruption. Leaving a stream, which flows at the bottom of a deep valley in a sandstone country, he climbs the steep acclivity of a hill, where he observes the edges of strata of sandstone and shale dipping inwards to-

Fig. 113.

The Gemunder Maar.

Fig. 114.



a. Village of Gemund. b. Gemunder Maar. c. Weinfelder Maar. d. Schalkenmehren Maar.

wards the mountain. When he has ascended to a considerable height, he sees fragments of scoriæ sparingly scattered over the surface; till at length, on reaching the summit, he finds himself suddenly on the edge of a *tarn*, or deep circular lake-basin.

This, which is called the Gemunder Maar, is the first of three lakes which are in immediate contact, the same ridge forming the barrier of two neighbouring cavities (see Fig. 113.). On viewing the first of these we recognize the ordinary form of a crater, for which we have been prepared by the occurrence of scoriæ scattered over the surface of the soil. But on examining the walls of the crater, we find precipices of sandstone and shale which exhibit no signs of the action of heat; and we look in vain for those beds of lava and scoriæ, dipping in opposite directions on every side, which we have been accustomed to consider as characteristic of volcanic craters. As we proceed, however, to the opposite side of the lake, and afterwards visit the craters *c* and *d* (Fig. 114.), we find a considerable quantity of scoriæ and some lava, and see the whole surface of the soil sparkling with volcanic sand, and strewed with ejected fragments of half-fused shale, which preserves its laminated texture in the interior, while it has a vitrified or scoriform coating.

A few miles to the south of the lakes above mentioned occurs the Pulvermaar of Gillenfeld, an oval lake of very regular form, and surrounded by an unbroken ridge of fragmentary materials, consisting of ejected shale and sandstone, and preserving a uniform height of about 150 feet above the water. The side slope in the interior is at an angle of about forty-five degrees; on the exterior, of thirty-five degrees. Volcanic substances are intermixed very sparingly with

the ejections, which in this place entirely conceal from view the stratified rocks of the country.*

The Meerfelder Maar is a cavity of far greater size and depth, hollowed out of similar strata; the sides presenting some abrupt sections of inclined secondary rocks, which in other places are buried under vast heaps of pulverized shale. I could discover no scoriæ amongst the ejected materials, but balls of olivine and other volcanic substances are mentioned as having been found.† This cavity, which we must suppose to have discharged an immense volume of gas, is nearly a mile in diameter, and is said to be more than one hundred fathoms deep. In the neighbourhood is a mountain called the Mosenberg, which consists of red sandstone and shale in its lower parts, but supports on its summit a triple volcanic cone, while a distinct current of lava is seen descending the flanks of the mountain. The edge of the crater of the largest cone reminded me much of the form and characters of that of Vesuvius.

If we pass from the Upper to the Lower Eifel, we find the celebrated lake-crater of Laach, which has a greater resemblance than any of those before mentioned to the Lago di Bolsena, and others in Italy — being surrounded by a ridge of gently sloping hills, composed of loose tuffs, scoriæ, and blocks of a variety of lavas.

One of the most interesting volcanos on the left bank of the Rhine is called the Roderberg. It forms a circular crater nearly a quarter of a mile in diameter, and one hundred feet deep, now covered with fields of

* Scrope, Edin. Journ. of Sci., June, 1826, p. 145.

† Hibbert, Extinct Volcanos of the Rhine, p. 24.

corn. The highly inclined greywacké strata rise even to the rim of one side of the crater; but they are overspread by quartzose gravel, and this again is covered by volcanic scoriæ and tufaceous sand. The opposite wall of the crater is composed of cinders and scorified rock, like that at the summit of Vesuvius. It is quite evident that the eruption in this case burst through the greywacké and alluvium which immediately overlies it; and I observed some of the quartz pebbles mixed with scoriæ on the flanks of the mountain, as if they had been cast up into the air, and had fallen again with the volcanic ashes.

I have already observed, that a large part of this crater has been filled up with loess, and I have pointed out how far we may thus obtain a relative date for the period of its eruption.*

The most striking peculiarity of a great many of the craters above described, is the absence of any signs of alteration or torrefaction in their walls, when these are composed of regular strata of greywacké-sandstone and shale. It is evident that the summits of hills formed of the above mentioned stratified rocks have, in some cases, been carried away by gaseous explosions, while at the same time no lava, and often a very small quantity only of scoriæ has escaped from the newly formed cavity. There is, indeed, no feature in the Eifel volcanos more worthy of note, than the proofs they afford of very copious aëriform discharges, unaccompanied by the pouring out of melted matter, except, here and there, in very insignificant volume. I have seen no assemblage of extinct volcanos in France, Italy, or Spain, where gaseous explosions of such magnitude

* See p. 48.

have been attended by the emission of so small a quantity of lava. Yet I looked in vain in the Eifel for any appearances which could lend support to the hypothesis, that the sudden rushing out of such enormous volumes of gas had ever lifted up the stratified rocks immediately around the vent, so as to form conical masses, having their strata dipping outwards on all sides from a central axis. In the Gemunder Maar the beds, as before stated, have an inward dip on one side of the hill; and in the walls of this and other craters, there are strata which are inclined at all angles, just as may be observed in the greywacké, far from the points of eruption. Those who favour the theory of the elevation crater might naturally expect, that in a district where so many tremendous explosions have occurred, they would find masses of greywacké towering several thousand feet above the surrounding platform, whereas the height of these ancient rocks has not been visibly affected by the sites of the extinct volcanos.*

Trass and its origin. — It appears that in the Lower Eifel eruptions of trachytic lava preceded the emission of currents of basalt, and that immense quantities of pumice were thrown out wherever trachyte issued. In this district, also, we find the tufaceous alluvium of the Rhine volcanos called *trass*, which has covered large areas, and choked up some valleys now partially re-excavated. This trass is unstratified; and its base consists almost entirely of pumice, in which are included fragments of basalt and other lavas, pieces of burnt shale, slate, and sandstone, and numerous trunks and branches of trees.

* See Vol. II. p. 205.

We may easily conceive the manner of its origin, if we reflect on what would happen if an eruption, attended by a copious evolution of gases, should now occur in one of the lake basins. The water might remain for weeks in a state of violent ebullition, until it became of the consistency of mud, just as the sea continued to be charged with red mud round Graham's Island, in the Mediterranean, in the year 1831.* If a breach should then be made in the side of the cone, the flood would sweep away great heaps of ejected fragments of shale and sandstone, which would be borne down into the adjoining valleys. Forests might be torn up by such a flood ; and thus the occurrence of the numerous trunks of trees dispersed irregularly through the trass, can be explained.

Age of the volcanic rocks. — It will be seen by the map (Fig. 112.), that the volcanic rocks extend also to the opposite or right bank of the Rhine, where they are spread over parts of the Westerwald, and form the great mass of the mountains called the Siebengebirge. They consist partly of basaltic and partly of trachytic lavas, the latter description being, in general, the more ancient of the two. There are many varieties of trachyte, some of which are highly crystalline, resembling a coarse-grained granite, with large separate crystals of felspar. Trachytic tuff is also very abundant. It is a difficult task to determine the age of all these igneous rocks, although their position, relatively to the stratified formations with which they are associated, has been clearly made out. The accompanying table presents in a synoptical view the series of rocks of the district delineated in the map (Fig. 112.).

* See Vol. II. p. 200.

a. Volcanic. *b.* Loess. *c.* Gravel. *b.* Loess. *a.* Volcanic.	A. Newer Pliocene.
d. Volcanic. *e.* Gravel. *f.* Brown coal. *g.* Volcanic. *f.* Brown coal.	B. Tertiary — of uncertain periods, but older than A.
Greywacké.	C.

It will be seen that the greywacké C, before alluded to (p. 115.), is the lowest rock of the series, which is usually in highly inclined strata; upon this reposes a nearly horizontal tertiary formation *f*, which has been called "brown coal." This deposit consists of beds of loose sand and sandstone, clay with nodules of clay-ironstone, and siliceous conglomerate. Beds of light brown and sometimes black lignite, of various thickness, are interstratified with the clays and sands, and often irregularly diffused through them. They are extensively worked for fuel, and hence the name given to the whole formation: they contain numerous impressions of leaves and stems of trees. In several places layers of trachytic tuff are interstratified, and in these tuffs are leaves of plants identical with those found in the brown coal, showing that during the period of the accumulation of the latter, some volcanic products (*g*) were ejected.

A vast deposit of gravel, *e*, chiefly composed of pebbles of white quartz, but containing also a few fragments of other rocks, lies over the brown coal formation, forming sometimes only a thin covering, at others attaining a thickness of more than 100 feet.

This gravel is very distinct in character from that now forming the bed of the Rhine. It is called "Kiesel gerolle" by the Germans, often reaches great elevations, and is covered in several places with volcanic ejections. It is evident that the country has undergone great changes in its physical geography since this gravel was formed, whereas no inconsiderable proportion of the volcanic rocks, *d*, were produced after the country had nearly attained its present configuration.

The aqueous and igneous formations above enumerated, constituting the group B, may be declared to be tertiary, from the character of the organic remains of the brown coal *f*; for they are seen to be either of the same age as *f*, or newer, and the members of the group A have been shown to be so intimately connected with the loess*, that we may, without hesitation, declare them to belong to the Newer Pliocene period. It should be recollected, however, that the whole series A only forms, in the aggregate, a very insignificant feature in the district, and the great mass of the volcanic products, *d*, may, possibly, belong to the Older Pliocene, or some still more remote era.

The varieties of wood found in the brown coal strata are said to belong entirely to dicotyledonous trees; but among the impressions of leaves, collected by Mr. Horner, some were referred by Mr. Lindley to a palm, and others resembled the Cinnamomum dulce, and Podocarpus macrophylla, which would also indicate a warm climate.†

The other organic remains of the brown coal are

* See pp. 46. 48.

† Proceedings of Geol. Soc., 1833. p. 469.

principally fishes; they are found in a bituminous shale, called paper-coal, from being divisible into extremely thin leaves. The individuals are extremely numerous; but they appear to belong to about five species, which M. Agassiz informs me are all extinct, and hitherto peculiar to this brown coal. They belong to the fresh-water genera Leuciscus, Aspius, and Perca. The remains of frogs also, of an extinct species, have been discovered in the paper coal; and a complete series may be seen in the museum at Bonn, from the most imperfect state of the tadpole to that of the full-grown animal. With these a salamander, scarcely distinguishable from the recent species, has been found, and several remains of insects.

The brown coal was evidently a fresh-water formation; but the extreme rarity of shells renders it difficult to form any conjecture as to the subdivision of the tertiary period to which it may belong. Near Marienforst, in the vicinity of Bonn, large blocks are found of a white opaque chert, containing numerous casts of fresh-water shells, which appear to belong to Planorbis rotundatus and Limnea longiscata, two species common both to the Eocene and Miocene periods, but which have not been found in any newer deposits. M. Deshayes, to whom I showed the specimens, said he felt as confident of the above identifications as *mere casts* would warrant. These blocks of chert are not *in situ,* but they probably belong to the brown coal formation, of which the hills at Marienforst consist. The brown coal is well known to contain, at other places, subordinate beds of silex. It is to be hoped, that a comparison of the organic remains of the brown coal with those of the tertiary formation of

Mayence, which appears to be of Miocene date, will throw some light on the chronological relations of the igneous and freshwater formations above considered.*

* For fuller details consult Noeggerath's Rheinland Westphalen, Memoirs of Von Dechen, Oeynhausen, and Von Buch, Steininger (erloschenen Vulkane in der Eifel, &c., Mainz, 1820), Van der Wyck (Uebersicht der Rheinischen und Eifeler erlosch. Vulkane, Bonn. 1826), Scrope (Edin. Journ. of Sci. 1826, p. 145.), Daubeny (Volcanos, p. 45.), Leonhard (Ueber Basalt-Gebilde), Hibbert (Extinct. Volcs. of Rhine), and the Memoir above cited by Mr. Horner.

CHAPTER XV.

MIOCENE FORMATIONS — MARINE.

Miocene period — Marine formations — Faluns of Touraine — compared to the English crag — Basin of the Gironde and Landes — Fresh-water limestone of Saucats, (p. 134.)—Eocene strata in the Bordeaux basin. — Position of the limestone of Blaye — Inland cliff near Dax — Montpellier — Strata of Piedmont — Superga — Valley of the Bormida — Molasse of Switzerland, (p. 140.) — Basin of Vienna — Styria — Hungary — Volhynia and Podolia — Mayence.

Having treated in the preceding chapters of the older and Newer Pliocene formations, I shall next consider those members of the tertiary series for which I have proposed the name of Miocene. The distinguishing characters of this group, as derived from its imbedded fossil testacea, have been explained in the fifth chapter.* In regard to the relative *position* of the strata, they underlie the Older Pliocene, and overlie the Eocene formations, when any of these happen to be present.

The area covered by the marine, fresh-water, and volcanic rocks of the Miocene period, in different parts of Europe, can already be proved to be very considerable; for they occur in Touraine, in the basin of the Loire, and still more extensively in the South of France,

* Vol. III. p. 392.

between the Pyrenees and the Gironde. They have also been observed in Piedmont, near Turin, and in the neighbouring valley of the Bormida, where the Apennines branch off from the Alps. They are largely developed in the neighbourhood of Vienna and in Styria; they abound in parts of Hungary; and they overspread extensive tracts in Volhynia and Podolia.

Shells characteristic of the Miocene strata are found in all these countries, figures of some of which are given in Plate XII., the species here selected abounding in almost all the deposits of this era, and not occurring in any Eocene or Pliocene formations. Cardita Ajar, however, is also a recent species, but has been admitted on account of its abundance in Miocene strata, and because it has never yet been observed in any *Pliocene* deposit, and is confined in a living state to tropical countries, as Senegal.

I shall now proceed to notice briefly some of the countries before enumerated as containing monuments of the era under consideration.

Touraine. — I have already alluded to the proofs of superposition adduced by M. Desnoyers, to show that the shelly strata provincially called "the Faluns of the Loire," were posterior to the most recent freshwater formation of the basin of the Seine. Their position, therefore, shows that they are of newer origin than the Eocene strata,—more recent, at least, than the uppermost beds of the Paris basin. But an examination of their fossil contents proves also that they are referrible to that type which distinguishes the Miocene period. When 300 of the Touraine shells collected by M. Desnoyers were compared by M. Deshayes with more than 1100 of the Parisian species, there were scarcely more than 20 which could

1. *Voluta rarispina*, Lam.k — 2. *Mitra Dufrenei*, Bast. — 3. *Pleurotoma denticula*, Bast.
4. *Nerita Plutonis*, Brong. — 5. *Turritella Proto*, Bast. — 6 *Fasciolaria turbinelloides*, Desh.
7. *Pleurotoma tuberculosa*, Bast. — 8. a.b. *Cardita Ajar*, Brug.

London, Published by John Murray 1833.

be identified; and on the other hand, the fossil shells of the Touraine beds agree far less with the testacea now inhabiting our seas than do the shells of the Older Pliocene strata of Northern Italy.

It is not merely in the basin of the Loire that the superposition of the Miocene to the Eocene strata has been observed; but in the Cotentin (see Map, chap. xx.), and in the environs of Rennes in Brittany.

The Miocene strata of the Loire have been observed to repose on a great variety of older rocks between Sologne and the sea, in which line they are seen to rest successively upon gneiss, clay-slate, coal-measures, Jura limestone, greenstone, chalk, and lastly upon the upper fresh-water deposits of the basin of the Seine. They consist principally of quartzose gravel, sand, and broken shells. The components are generally incoherent, but sometimes agglutinated together by a calcareous or earthy cement, so as to serve as a building stone. Like the shelly portion of the crag of Norfolk and Suffolk, the *faluns* and associated strata are of slight thickness, not exceeding seventy feet. They often bear a close resemblance to the crag in appearance, the shells being stained of the same ferruginous colour, and being in the same state of decay; serving in Touraine, just as in Norfolk and Suffolk, to fertilize the arable land. Like the crag, also, they contain mammiferous remains, which are not only intermixed with marine shells, but sometimes encrusted with serpulæ, flustra, and balani. These terrestrial quadrupeds belong to the genera Mastodon, Rhinoceros, Hippopotamus, &c., the assemblage, considered as a whole, being very distinct from those of the Paris gypsum.*

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 443.

The faluns and contemporary strata of the basin of the Loire may be considered generally as having been formed in a shallow sea, into which a river, flowing perhaps from some of the lands now drained by the Loire, introduced from time to time fluviatile shells, wood, and the bones of quadrupeds, which may have been washed down during floods. Some of these bones have precisely the same black colour as those found in the peaty shell-marl of Scotland; and we might imagine them to have been dyed black in *Miocene peat*, which was swept down into the sea during the waste of cliffs, did we not find the remains of cetacea in the same strata—bones, for example, of the lamantine, morse, sea-calf, and dolphin, having precisely the same colour.

The resemblance which M. Desnoyers has pointed out as existing between the English *crag* and the French *faluns* is one which ought by no means to induce us to ascribe a contemporaneous origin to these two groups, but merely a similarity of geographical circumstances at the respective periods when each was deposited. In every age, where there is land and sea, there must be shores, shallow estuaries, and rivers; and near the sea-coasts banks of marine shells and corals may accumulate. It must also be expected that rivers will drift in fresh-water shells, together with sand and pebbles, and occasionally, perhaps, sweep down the carcasses of land quadrupeds into the sea. If the sand and shells, both of the "crag" and "faluns," have each acquired the same ferruginous colour, such a coincidence would merely lead us to infer that, at each period, there happened to be springs charged with iron, which flowed into some part of the

sea or basin of the river, by which the sediment was carried down into the sea.

Even had the French and English strata which we are comparing shared a greater number of mineral characters in common, that identity could not have justified us in inferring the synchronous date of the two groups, where the discordance of fossil remains is so marked. The argument which infers a contemporaneous origin from correspondence of mineral contents, proceeds on the supposition that the materials were either washed down from a common source, or, being derived from different sources, were mingled together in a common receptacle. If, according to the latter hypothesis, the crag and the faluns were thrown down in one continuous sea, the testacea could not have been so distinct in two regions not more distant from each other than Essex and the mouth of the Loire, unless we assume that the laws which regulated the geographical distribution of species were then very different from those now prevailing. But if it be said that the two basins may have been separated from each other, as are those of the Mediterranean and Red Sea, by an isthmus, and that distinct assemblages of species may have flourished in each, as is now actually the case in those two seas *, I may reply, that such narrow lines of demarcation are extremely rare now, and must have been infinitely more so in remoter tertiary epochs; because there can be no doubt that the proportion of land to sea has been greatly on the increase in European latitudes during the more modern geological eras.

In the *faluns*, and in certain groups of the same age,

* See above, chap. x.

which occur not far to the west of Orleans, M. Desnoyers has discovered the following mammiferous quadrupeds:—*Palæotherium magnum*, *Mastodon angustidens*, *Hippopotamus major* and *H. minutus*, *Rhinoceros leptorhinus* and *R. minutus*, *Tapir gigas*, *Anthracotherium* (small species), *Sus*, *Equus* (small species), *Cervus*, and an undetermined species of the Rodentia.

The first species on this list is common to the Paris gypsum, and is therefore an example of a land quadruped common to the Miocene and Eocene formations, an exception perfectly in harmony with the results obtained from the study of fossil shells.*

Basin of the Gironde and district of the Landes.—A great extent of country between the Pyrenees and the Gironde is overspread by tertiary deposits, which have been more particularly studied in the environs of Bordeaux and Dax, from whence about six hundred species of shells have been obtained. These shells belong to the same zoological type as those of Touraine.†

Most of the beds near Dax, whence these shells are procured, consist of incoherent quartzose sand, mixed for the most part with calcareous matter, which has often bound together the sand into concretionary nodules. A great abundance of fluviatile shells occurs in many places intermixed with the marine; and in some localities microscopic shells are in great profusion.

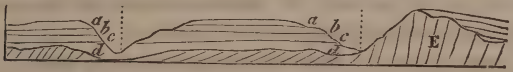
* For further details respecting the basin of the Loire, see M. Desnoyers, Ann. des Sci. Nat., tome xvi. pp. 171. 402., where full references to other authors are given.

† M. de Basterot has given a description of more than three hundred shells of Bordeaux and Dax, and figures of the greater number of them. Mém. de la Soc. d'Hist. Nat. de Paris, tome ii.

The tertiary deposits in this part of France vary much in their mineralogical character, yet admit generally of being arranged in four groups. See diagram, Fig. 115.

In some places the united thickness of these groups is considerable; but in the country between the Pyrenees and the valley of the Adour around Dax, the disturbed secondary rocks are often covered by a thin pellicle only of tertiary strata, which rests horizontally on the chalk, and does not always conceal it.

Fig. 115. Adour R. Luy R. Puy Arzet.



Tertiary strata overlying chalk in the environs of Dax.

a. Siliceous sand without shells. *c.* Sand and marl with shells.
b. Gravel. *d.* Blue marl with shells.
E. Chalk and volcanic tuff.

In the valleys of the Adour and Luy, sections of all the members of the tertiary series are laid open; but the lowest blue marl, which is sometimes two hundred feet thick, is not often penetrated. On the banks of the Luy, however, to the south of Dax, the subjacent white chalk is exposed in inclined and vertical strata. In the hill called Puy Arzet the chalk, characterized by its peculiar fossils, is accompanied by beds of volcanic tuff, which are conformable to it, and which may be considered as the product of submarine eruptions which took place in the sea wherein the chalk was formed. These tuffs must once have been nearly horizontal, but, like the chalky strata, have been subjected to great subsequent derangement.

About a mile west of Orthès, in the Bas Pyrénées, the blue marl is seen to extend to the borders of the

tertiary formation, and rises to the height probably of six or seven hundred feet. In that locality many of the marine Miocene shells preserve their original colours. This marl is covered by a considerable thickness of ferruginous gravel, which seems to increase in volume near the borders of the tertiary basin on the side of the Pyrenees.

In an opposite direction, to the north of Dax, the shelly sands often pass into calcareous sandstone, in which there are merely the casts of shells, as at Carcares; and into a shelly breccia, resembling some rocks of recent origin which I have received from the coral reefs of the Bermudas.

Fresh-water limestone at Saucats. —Associated with the Miocene strata near Bordeaux, at a place called Saucats, is a compact fresh-water limestone, of slight thickness, which is perforated on the upper surface by marine shells, for the most part of extinct species. It is evident that the space must have been alternately occupied by salt and fresh water. The ground, perhaps, may have been alternately raised and depressed, or a lagoon may have been formed, in which the water became fresh; then a barrier of sand, by which the sea was excluded for a time, may have been breached, so that the salt water again obtained access.

Eocene strata in the Bordeaux basin. — The relations of some of the members of the tertiary series, in the basin of the Gironde, have of late afforded matter of controversy. A limestone, resembling the calcaire grossier of Paris, and from one hundred to two hundred feet in thickness, occurs at Pauliac and Blaye, and extends on the right bank of the Gironde, between Blaye and La Roche. It contains many species of fossils identical with those of the Paris basin. This

fact was pointed out to me by M. Deshayes before I visited Blaye in 1830; but although I recognized the mineral characters of the rock to be very different from those of the Miocene formations in the immediate neighbourhood of Bordeaux, I had not time to verify its relative position. I inferred, however, the inferiority of the Blaye limestone to the Miocene strata, from the order in which each series presented itself, as I receded from the chalk and passed to the central parts of the Bordeaux basin.

Upon leaving the white chalk with flints, in travelling from Charente by Blaye to Bordeaux, I first found myself upon overlying red clay and sand (as at Mirambeau); I then came upon the tertiary limestone above alluded to, at Blaye; and lastly, on departing still farther from the chalk, reached the strata which, at Bordeaux and Dax, contain exclusively the Miocene shells.

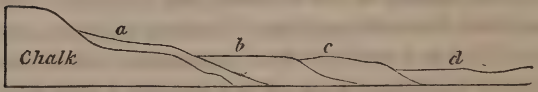
The occurrence both of Eocene and Miocene fossils in the same basin of the Gironde, had been cited by M. Boué as a fact which detracted from the value of zoological characters as a means of determining the chronological relations of tertiary groups. But on farther inquiry, the fact has been found to furnish additional grounds of confidence in these characters.

M. Ch. Desmoulins replied, to M. Boué's objections, that the assemblage of Eocene shells are never intermixed with those found in the "moellon," as he calls the sandy calcareous rock of the environs of Bordeaux and Dax; and M. Dufrénoy farther stated, that the hills of limestone which border the right bank of the Gironde, from Marmande as far as Blaye, present several sections wherein the Parisian (or Eocene) limestone is seen to be separated from the shelly

strata called "faluns," or "moellon," by a fresh-water formation of considerable thickness. It appears, therefore, that as the marine faluns of Touraine rest on a fresh-water formation, which overlies the marine calcaire grossier of Paris, so the marine Miocene strata of Bordeaux are separated from those of Blaye by a fresh-water deposit.*

The following diagram will express the order of position of the groups above alluded to.

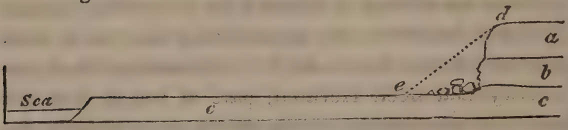
Fig. 116.



a. Red clay and sand.
b. Limestone like calcaire grossier, sometimes alternating with green marl, and containing Eocene shells.
c. Fresh-water formation, same as that of the department of Lot and Garonne.
d. Tertiary strata of the Landes, with Miocene fossils.

Inland cliff near Dax. — A few miles west from Dax, and at the distance of about twelve miles from the sea, a steep bank is seen running in a direction nearly north-east and south-west, or parallel to the contiguous coast. This steep declivity, which is about fifty feet in height, conducts us from the higher plat-

Fig. 117.



Section of Inland Cliff at Abesse, near Dax.

a. Sand of the Landes. *b*. Limestone. *c*. Clay.

* Bulletin de la Soc. Géol. de France, tome ii. p. 440.

form of the Landes to a lower plain which extends to the sea. The outline of the ground might suggest to every geologist the opinion that the bank in question was once a sea-cliff, when the whole country stood at a lower level relatively to the sea. But this can no longer be regarded as matter of conjecture. In making excavations recently for the foundation of a building at Abesse, a quantity of loose sand, which formed the slope *d e*, was removed; and a perpendicular cliff, about fifty feet in height, which had hitherto been protected from the agency of the elements, was exposed. The bottom of this cliff consists of limestone *b*, which contains shells and corals of Miocene species, and is probably a calcareous form of the division *c* (Fig. 115. p. 133.) Immediately below this limestone is the clay, *c* (probably *d*, Fig. 115., *ibid.*); and above it the usual tertiary sand, *a*, of the department of the Landes. At the base of the precipice are seen large partially rounded masses of rock, evidently detached from the stratum *b*. The face of the limestone is hollowed out and weathered into such forms as are seen in the calcareous cliffs of the adjoining coast, especially at Biaritz, near Bayonne, where the spot was pointed out to me by the proprietor of the lands of Abesse in 1830. It is evident that, when the country was at a somewhat lower level, the sea advanced along the surface of the argillaceous stratum *c*, which, from its yielding nature, favoured the waste by undermining the more solid superincumbent limestone *b*. Afterwards, when the country had been elevated, part of the sand, *a*, fell down, or was drifted by the winds, so as to form the talus, *d e*, which masked the inland cliff until it was artificially laid open to view.

The situation of this cliff is interesting, as marking

one of the pauses which intervened between the successive movements of elevation by which the marine tertiary strata of this country were upheaved to their present height, a pause which allowed time for the sea to advance and strip off the upper beds *a*, *b*, from the denuded clay *c*.

Montpellier.—The tertiary strata of Montpellier contain many of the Dax and Bordeaux species of shells, so that they are probably referrible to the Miocene epoch; but in the catalogue given by M. Marcel de Serres, many *Pliocene* species, similar to those of the Subapennine beds, are enumerated. M. de Christol mentions Mastodon angustidens, Rhinoceros leptorhinus, a Tapir, a Palæotherium, and an Anthracotherium, together with many other mammifers, besides cetacea and reptiles.*

It would be highly interesting if, upon fuller investigation, the Montpellier beds should be found to indicate a passage from the fossils of the Miocene type to those of the Older Pliocene. We may expect the discovery of such intermediate links, and I have endeavoured to provide a place for them in the classification proposed in the fifth chapter.†

Hills of Mont Ferrat and the Superga. — The late Signor Bonelli of Turin was the first who remarked that the tertiary shells found in the green sand and marl of the Superga near Turin differed, as a group, from those generally characteristic of the Subapennine beds. The same naturalist had also observed, that many of the species peculiar to the Superga were identical with those occurring near Bordeaux and

* Résumé de M. Boué, p. 128. Bull. de la Soc. Géol. de France, tom. iii.

† Vol. III. p. 397.

Dax. The strata of which the hill of the Superga is composed are inclined at an angle of more than seventy degrees, as I found when I examined the Superga in company with Mr. Murchison in 1828. They consist partly of fine sand and marl, and partly of a conglomerate composed of primary boulders, which forms a lower part of the series, and not, as represented by M. Brongniart by mistake*, an unconformable and overlying mass. The same series of beds is more largely developed in the chain of Mont Ferrat, especially in the basin of the Bormida. The high road which leads from Savona to Alessandria intersects them in its northern descent, and the formation may be well studied along this line at Carcare, Cairo, and Spinto, at all which localities fossil shells occur in a bright green sand. At Piana, a conglomerate, interstratified with this green sand, contains rounded blocks of serpentine and chlorite schist, larger than those near the summit of the Superga, some of them being not less than nine feet in diameter.

When we descend to Aqui, we find the green sand giving place to bluish marls, which also skirt the plains of the Tanaro at lower levels. These newer marls are associated with sand, and are nearly horizontal, and appear to belong to the Older Pliocene Subapennine strata.† The shells which characterize the latter abound in various parts of the country near Turin; but that region has not yet been examined with sufficient care to enable us to give exact sections to illustrate the superposition of the Miocene and Older Pliocene

* Terrains du Vicentin, p. 26.

† See section, Fig. 64. Vol. III., p. 360.

beds. It is, however, ascertained, that the highly inclined green sand, which comes immediately in contact with the primary rocks, is the oldest part of the series.*

Molasse of Switzerland. — If we cross the Alps, and pass from Piedmont to Savoy, we find there, at the northern base of the great chain, and throughout the lower country of Switzerland, a soft green sandstone much resembling some of the beds of the basin of the Bormida, above described, and associated in a similar manner with marls and conglomerate. This formation is called in Switzerland "molasse," said to be derived from "mol," "*soft*," because the stone is easily cut in the quarry. It is of vast thickness, but shells have so rarely been found in it that they do not supply sufficient data for correctly determining its age. M. Studer, in his treatise on the "molasse," enumerates some fossil shells found near Lucerne, agreeing, apparently, with those of the Subapennine hills. The correspondence in mineral character between the green sand of Piedmont and that of Switzerland can in nowise authorise us to infer identity of age, but merely to conclude that both have been derived from the degradation of similar ancient rocks.

Until the place of the "molasse" in the chronological series of tertiary formations has been more rigorously determined, the application of this provincial

* Piedmont is not wanting in able and zealous cultivators of Geology and Zoology, and it is to be hoped that MM. Pareto, Passini, Sismonda, and La Marmora will devote their attention to the relative position of the several groups of tertiary strata in their country, by instituting a comparison between their respective organic remains.

name to the tertiary groups of other countries must be very uncertain, and it will be desirable to confine it to the tertiary beds of Switzerland.

Styria, Vienna, Hungary. — Of the various groups which have hitherto been referred to the Miocene era, none are so important in thickness and geographical extent as those which are found at the eastern extremity of the Alps, in what have been termed the basins of Vienna and Styria, and which spread thence into the plains of Hungary. The collection of shells formed by M. Constant Prevost, in the neighbourhood of Vienna, and described by him in 1820 *, was alone sufficient to identify a great part of the formations of that country with the Miocene beds of the Loire, Gironde, and Piedmont. The fossil remains subsequently procured by that indefatigable observer M. Boué have served to show the still greater range of the same beds through Hungary and Transylvania.

It appears from the recently published memoirs of Professor Sedgwick and Mr. Murchison †, that the formations of Styria may be divided into groups corresponding to those adopted by M. Partsch for the Vienna beds; the basin of Styria exhibiting nearly the same phenomena as that of Vienna. These regions have evidently formed, during the Miocene period, two deep bays of the same sea, separated from each other by a great promontory connected with the central ridge of the eastern Alps.

The English geologists above mentioned describe a long succession of marine strata intervening between the Alps and the plains of Hungary, which are divi-

* Journal de Physique, Novembre, 1820.

† Geol. Trans., Second Series, vol. iii. p. 301.

sible into three natural groups, each of vast thickness, and affording a great variety of rocks. All these groups are of marine origin, and lie in nearly horizontal strata, but have throughout a slight easterly dip; so that in traversing them from west to east, we commence with the oldest, and end with the youngest beds.

At their western extremity they fill an irregular trough-shaped depression, through which the waters of the Mur, the Raab, and the Drave, make their way to the lower Danube.* Here the first group is developed, consisting of conglomerate, sandstone, and marls, some of the marls containing marine shells. Beds also of lignite occur, showing that wood was drifted down in large quantities into the sea. In parts of the series there are masses of rounded siliceous pebbles, resembling the shingle banks which are forming on some of our coasts.

The second principal group is characterized by coralline and concretionary limestone of a yellowish white colour; it is finely exposed in the escarpments of Wildon, and in the hills of Ehrenhausen, on the right bank of the Mur.† This coralline limestone is not less than 400 feet thick at Wildon, and exceeds, therefore, some of the most considerable of our secondary groups in England.‡

Beds of sandstone, sand, and shale, and calcareous marls, are associated with the above-mentioned limestone.

The third group, which occurs at a still greater distance from the mountains, is composed of sandstone

* Geol. Trans., Second Series, vol. iii. p. 382.

† Ibid., p. 385. ‡ Ibid., p. 390.

and marl, and of beds of limestone, exhibiting here and there a perfectly oolitic structure. In this system fossil shells are numerous.

In regard to the age of the formations above described, it is by no means clear that the coralline limestones of the second group are posterior in origin to all the beds of the first division; they may possibly have been formed at some distance from land, while the head of the gulf was becoming filled up with enormous deposits of gravel, sand, and mud, which may, in that quarter, have rendered the waters too turbid for the fullest development of testaceous and coralline animals.

The middle group, both in the basins of Styria and Vienna, belongs indisputably to the Miocene period; for the species of shells are the same as those of the Loire, Gironde, and other contemporary basins before noticed. Whether the lowest and uppermost systems are referrible to the same, or to distinct tertiary epochs, is the only question. We cannot doubt that the accumulation of so vast a succession of beds required an immense lapse of ages, and we should expect to find some difference in the species characterizing the different members of the series; nevertherless, all may belong to different subdivisions of the Miocene period. Professor Sedgwick and Mr. Murchison have suggested that the inferior, or first group, which comprises the strata between the Alps and the coralline limestone of Wildon, may correspond in age to the Paris basin; but the list of fossils which they have given seems rather to favour the supposition that the deposit is of the Miocene era. They mention four characteristic Miocene fossils, — Mytilus Brardii, Cerithium pictum, C. pupæforme, and C. plicatum; — and though some few

of the associated shells are common to the Paris basin, such a coincidence is no more than holds true in regard to all the European Miocene formations.

On the other hand, the third or newest system, which overlies the coralline limestone, contains fossils which do not appear to depart so widely from the Miocene type as to authorize us to separate them. They appear to agree with the tertiary strata of a great part of Hungary and Transylvania, which are referrible to the Miocene period.*

Volhynia and Podolia. — We may expect to find many other districts in Europe composed of Miocene strata; and there is already sufficient evidence that the marine deposits of the platform of Volhynia and Podolia were of this era. The fossils of that region, which is bounded by Galicia on the west, and the Ukraine on the east, and comprises parts of the basins of the Bog and the Dneister, has been investigated by Von Buch, Eichwald, and Du Bois; and the latter has given excellent plates of more than one hundred fossil shells of the country, which M. Deshayes finds to agree decidedly with the fossils of the Miocene period.†

The formation consists of sand and sandstone, clay, coarse limestone, and a white oolite, the last of which is of great extent.

Mayence. — The tertiary strata near Mayence contain in abundance the Mytilus Brardii, and several other characteristic Miocene fossils. They occupy a tract from five to twelve miles in breadth, extending along the left bank of the Rhine from Mayence to the neigh-

* See tables of shells by M. Deshayes, in Appendix I. of the octavo edition.

† Conch. Foss. du Plateau Wolhyni-Podol., par F. du Bois. Berlin, 1831.

bourhood of Manheim, and are again found to the east, north, and south-west of Frankfort. In some places they have the appearance of a fresh-water formation; but in others, as at Alzey, the shells are for the most part marine. Cerithia are in great profusion, which indicates that the sea where the deposit was formed was fed by rivers; and the great quantity of fossil land shells, chiefly of the genus Helix, confirm the same opinion. The variety in the species of shells is small, scarcely eighty having yet been discovered, as I learn from Professor Bronn, of Heidelberg, while the individuals are exceedingly numerous; a fact which accords perfectly with the idea that the formation may have originated in a gulf or sea, which, like the Baltic, was brackish in some parts and almost fresh in others. A species of Paludina, very nearly resembling the recent Littorina ulva, is found throughout this basin. These shells may be compared in size to grains of rice, and often are in such quantity as to form almost entire strata of marl and limestone. I have seen them as thick as grains of sand, in stratified masses fifteen feet thick; and Professor Bronn has observed a succession of beds thirty feet in thickness, of which they are the principal constituent.

I was unable to find any natural sections which exhibited the relations of the Mayence strata above described to the sandy beds of Eppelsheim, wherein the new genus Deinotherium, and the bones of the Mastodon avernensis and other mammifers, have been discovered. But I think it most probable that they all belong to the same era, and that the fresh-water beds of Georges Gemund, in Bavaria, as well as several other detached lacustrine groups of that country and of Wurtemburg, may be referred to the Miocene period.

At Georges Gemund, as in Touraine, we find an association of the genera Palæotherium, Mastodon, and Rhinoceros.

Osnabruch. — From the fossils which I have seen in the cabinet of Count Munster at Bayreuth, I have little doubt that strata of the Miocene period are largely developed between the mountains of the Teutobourgerwald and Wesergebirge, including the environs of Osnabruch, Münster, Astrupp, and other places.

CHAPTER XVI.

MIOCENE FORMATIONS — ALLUVIAL — FRESH-WATER — VOLCANIC.

Miocene alluviums — Auvergne — Mont Perrier — Extinct quadrupeds — Velay — Orleanais — Alluviums contemporaneous with Faluns of Touraine — Miocene fresh-water formations — Upper Val d'Arno — Extinct mammalia (p. 151.) — Coal of Cadibona — Miocene volcanic rocks — Hungary — Transylvania — Styria — Auvergne — Velay.

In the present chapter I shall offer some observations on the alluviums and fresh-water formations of the Miocene era, and shall afterwards point out the countries in Europe where the volcanic rocks of the same period may be studied.

Miocene Alluviums.

Auvergne. — The annexed drawing will explain the position of two ancient beds of alluvium, *c* and *e*, in

Fig. 118.

Position of the Miocene alluviums of Mont Perrier (or Boulade).

Descending series.

a. Newer alluvium. *b.* Second trachytic breccia.
c. Second Miocene alluvium with bones.
d. First trachytic breccia.
e. First Miocene alluvium with bones.
f Compact basalt. *g.* Eocene lacustrine strata.

Auvergne, in which the remains of several quadrupeds characteristic of the Miocene period have been obtained. In order to account for the situation of these beds of rounded pebbles and sand, we must suppose that after the tertiary strata *g*, covered by the basaltic lava *f*, had been disturbed and exposed to aqueous denudation, a valley was excavated, wherein the alluvium *e* was accumulated, and in which the remains of quadrupeds then inhabiting the country were buried. The trachytic breccia *d* was then superimposed; this breccia is an aggregate of shapeless and angular fragments of trachyte, cemented by volcanic tuff and pumice, resembling some of the breccias which enter into the composition of the neighbouring extinct volcano of Mont Dor in Auvergne, or those which are found on Etna. Upon this rests another alluvium, *c*, which also contains the bones of Miocene species, and this is covered by another enormous mass of tufaceous breccia. The breccias have probably resulted from the sudden rush of large bodies of water down the sides of an elevated volcano at its moments of eruption, perhaps when snow was melted by lava. Such floods occur in Iceland, sweeping away loose blocks of lava and ejections surrounding the crater, and then strewing the plains with fragments of igneous rocks, enveloped in mud or "moya." The abrupt escarpment presented by the above-described beds, *b*, *c*, *d*, *e*, towards the valley of the Couze, must have been caused by subsequent erosion, which has carried away a large portion of those masses.*

* For an account of the position and age of the volcanic breccias of Mont Perrier and Boulade, see Lyell and Murchison on the Beds of Mont Perrier, Ed. New Phil. Journ., July, 1829, p. 15.

In the alluviums *c* and *e*, MM. Croizet, Jobert, Chabriol, and Bouillet have discovered the remains of about forty species of extinct mammalia, the greater part of which are peculiar as yet to this locality; but some of them are characteristic of the Miocene period, being common to the faluns of Touraine, and associated in other localities with marine Miocene strata. Among these species may be enumerated Mastodon minor and M. arvernensis, Hippopotamus major, Rhinoceros leptorhinus, and Tapir arvernensis. The Elephas primigenius, a species common to so many tertiary periods, is also stated to accompany the rest. In some cases the remains are not sufficiently characteristic to indicate the exact species, but the following genera can be determined:—The boar, horse, ox, hyæna (two species), felis (three or four), bear (three), deer (many species), canis, otter, beaver, hare, and water-rat.*

Velay.—In Velay a somewhat similar group of mammiferous remains were found by Dr. Hibbert† in a bed of volcanic scoriæ and tuff, inclosed between two beds of basaltic lava, at Saint Privat d'Allier. Some of the bones were found adhering to the slaggy lava. Among the animals were Rhinoceros leptorhinus, Hyæna spelæa, and another species allied to the spotted hyæna of the Cape, together with four undetermined species of deer.‡

At Cussac and Solilhac, one league from Puy en

* Recherches sur les Oss. Foss. du Dépt. du Puy de Dome, 4to. 1828. Essai Géol. et Minéral. sur les Environs d'Issoire, Dépt. du Puy de Dome, folio, 1827.

† Edin. Journ. of Sci., No. iv. New Series, p. 276.

‡ Figures of some of these remains are given by M. Bertrand de Doue, Ann. de la Soc. d'Agricult. de Puy, 1828.

Velay, M. Robert discovered, in an ancient alluvium covered with lava, the remains of Elephas primigenius, Rhinoceros leptorhinus, Tapir arvernensis, horse (two species), deer (seven species), ox (two species), and an antelope.

Orleanais.—In the Orleanais, at Avaray, Chevilly, les Aides, and les Barres, fossil land quadrupeds have been found associated with fluviatile shells and reptiles, identical with those found in the marine faluns of Touraine.* These are supposed with great probability, by M. Desnoyers, to mark the passage of streams which flowed towards the sea in which the faluns were deposited. They bear the same relation to the Miocene strata of Touraine, as the bones of elephants and other extinct animals, in the ancient gravel and silt of England, probably bear to the crag.

Miocene Fresh-water Formations.

Upper Val d'Arno.—There are a great number of isolated tertiary formations, of fresh-water origin, resting on primary and secondary rocks in different parts of Europe, in the same manner as we now find small lakes scattered over our continents and islands, wherein deposits are forming, quite detached from all contemporary marine strata. To determine the age of such groups, with reference to the great chronological series established for the marine strata, must often be a matter of difficulty, since we cannot always enjoy an opportunity of studying a locality where the fresh-water species are intermixed with marine shells, or where they occur in beds alternating with marine strata.

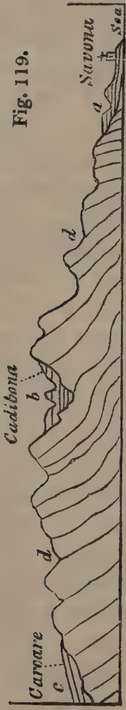
* MM. Desnoyers and Lockart, Bulletin de la Soc. Géol., tom. ii. p. 336.

The deposit of the Upper Val d'Arno before alluded to (p. 71.), was evidently formed in an ancient lake; but, although the fossil testaceous and mammiferous remains preserved therein are very numerous, it is scarcely possible, at present, to decide with certainty the precise era to which they belong. I collected six species of lacustrine shells, in an excellent state of preservation, from this basin, belonging to the genera Anodon, Paludina, and Neritina; but M. Deshayes was unable to identify any one of them with any recent or fossil species known to him. If the beds belonged to the Older Pliocene formations, we might expect that several of the fossils would agree specifically with living testacea; and I am therefore disposed to believe that they belong to an older epoch. If we consider the terrestrial mammalia of the same beds, we immediately perceive that they cannot be assimilated to the Eocene type, as exhibited in the Paris basin, or in Auvergne and Velay: but some of them agree with Miocene species. Mr. Pentland has obligingly sent me the following list of the fossil mammifers of the upper Val d'Arno which are in the museums of Paris.——*Feræ*—Ursus cultridens, Viverra Valdarnensis, Canis lupus (?), and another of the size of the common fox. Hyæna radiata, H. fossilis. Felis (a new species, of the size of the panther). *Rodentia* — Histrix, nearly allied to dorsalis, Castor. *Pachydermata* — Elephas Italicus, Mastodon angustidens, M. Taperoides, Tapir ——, Equus ——, Sus scrofa, Rhinoceros leptorhinus, Hippopotamus major, fossilis. *Ruminantia* —Cervus megaceros (?), C. Valdarnensis, C. —— (new species), Bos, bubalo affinis, B. urus and B. taurus.

Cuvier also mentions the remains of a species of

lophiodon as occurring among the bones in the Upper Val d'Arno.* The elephant of this place has been called by Nesti † *meridionalis*, and is considered by him as distinct from the Siberian fossil species *E. primigenius*, with which, however, some eminent comparative anatomists regard it as identical. The skeletons of the hippopotamus are exceedingly abundant; no less than forty had been procured when I visited Florence in 1828. Remains of the elephant, stag, ox, and horse, are also extremely numerous. In winter the superficial degradation of the soil is so rapid, that bones which the year before were buried are seen to project from the surface of the soil, and are described by the peasants as growing. In this manner the tips of the horns of stags, or of the tusks of hippopotamuses, often appear on the surface, and thus lead to the discovery of an entire head or skeleton.

Fig. 119.



Section of the fresh-water formation of Cadibona.

a. Blue marl and yellow sand (Older Pliocene). *b.* Sand, shale, and coal of Cadibona (Miocene ?). *c.* Green sand, &c. of the Bormida (Miocene). *d.* Chloritic and Micaceous schist, serpentine, &c.

Cadibona. — Another example of an isolated lacustrine deposit, belonging possibly to the Miocene period, is that which occurs at Cadi-

* Oss. Foss., vol. v. p. 504.

† Lettere sopra alcune Ossa Fossili del Val d'Arno, &c. Pisa, 1825.

bona, between Savona and Carcare, a place which I visited in August, 1828, in company with Mr. Murchison. Its position is described in the annexed section, which does not, however, pretend to accuracy in regard to the relative heights of the different rocks, or the distances of the places from each other. The lacustrine strata are composed of gravel, grit, and micaceous sandstone, of such materials as were derivable from the surrounding primary rocks; and so great is the thickness of this mass, that some valleys intersect it to the depth of seven or eight hundred feet without penetrating to the subjacent formations. In one part of the series, carbonaceous shales occur, and several seams of coal from two to six feet in thickness; but no impressions of plants of which the species could be determined, and no shells have been discovered. Many entire jaws and other bones of an extinct mammifer, called by Cuvier Anthracotherium, have been found in the coal-beds, the bone being itself changed into a kind of coal; but as this species has not as yet occurred elsewhere in association with organic remains of known date, it affords us no aid when we attempt to assign a place to the lignites of Cadibona.

Miocene Volcanic Rocks.

Hungary.—M. Beudant, in his elaborate work on Hungary, describes five distinct groups of volcanic rocks, which, although nowhere of great extent, form striking features in the physical geography of that country, rising as they do abruptly from extensive plains composed of tertiary strata. They may have constituted islands in the ancient sea, as Santorin and Milo now do in the Grecian Archipelago; and M. Beu-

dant has remarked that the mineral products of the last-mentioned islands resemble remarkably those of the Hungarian extinct volcanos, where many of the same minerals, as opal, calcedony, resinous silex (*silex resinite*), pearlite, obsidian, and pitchstone abound.

The Hungarian lavas are chiefly felspathic, consisting of different varieties of trachyte; many are cellular, and used as millstones; some so porous and even scoriform as to resemble those which have issued in the open air. Pumice occurs in great quantity; and there are conglomerates, or rather breccias, wherein fragments of trachyte are bound together by pumiceous tuff, or sometimes by silex.

It is probable that these rocks were permeated by the waters of hot springs, impregnated, like the Geysers, with silica; or, in some instances, perhaps, by aqueous vapours, which, like those of Lancerote, may have precipitated hydrate of silica.*

By the influence of such springs or vapours the trunks and branches of trees washed down during floods, and buried in tuffs on the flanks of the mountains, may have become silicified. It is scarcely possible, says M. Beudant, to dig into any of the pumiceous deposits of these mountains without meeting with opalized wood, and sometimes entire silicified trunks of trees of great size and weight.

It appears from the species of shells collected principally by M. Boué, and examined by M. Deshayes, that the fossil remains imbedded in the volcanic tuffs, and in strata alternating with them in Hungary, are of the Miocene type, and not identical, as was formerly supposed, with the fossils of the Paris basin.

* See Vol. II. p. 195.

Transylvania.—The igneous rocks of the eastern part of Transylvania, described by M. Boué, are probably of the same age. They cover a considerable area, and bear a close resemblance to the Hungarian lavas, being chiefly trachytic. Several large craters, containing shallow lakes, like the Maars of the Eifel, are met with in some regions; and a rent in the trachytic mountains of Budoshagy exhales hot sulphureous vapours, which convert the trachyte into alum-stone, a change which that rock has undergone at remote periods in several parts of Hungary.

Styria.—Many of the volcanic groups of this country bear a similar relation to the Styrian tertiary deposits, as do the Hungarian rocks to the marine strata of that country. The shells are found imbedded in the volcanic tuffs in such a manner as to show that they lived in the sea when the volcanic eruptions were in progress, as many of the Val di Noto lavas in Sicily, before described, were shown to be contemporaneous with Newer Pliocene strata.*

Auvergne—Velay.—I believe that part of the volcanic eruptions of Auvergne took place during the Miocene period; those, for example, which cover, or are interstratified with, the alluviums mentioned in this chapter, and some of the ancient basaltic cappings of hills in Auvergne, which repose on gravel characterized by similar organic remains. A part also of the igneous rocks of Velay must belong to this epoch; but these will be again referred to when I treat more fully of the volcanic rocks of Central France, the older part of which are referrible to the Eocene period.

* Sedgwick and Murchison, Geol. Trans., Second Series, vol. iii. p. 400. Daubeny, Extinct Volcanos, p. 92.

CHAPTER XVII.

EOCENE FRESH-WATER FORMATIONS.

Eocene period — Fresh-water formations — Central France — Map — Limagne d'Auvergne — Sandstone and conglomerate — Tertiary red marl and red sandstone — Green and white foliated marls (p. 162.)— Indusial limestone — Gypseous marls — Travertin — Fresh-water formation of Puy en Velay (p. 170.) — Of Cantal — Resemblance of Aurillac limestone and flints to our upper chalk — Concluding remarks.

We have now traced back the history of the European formations to that period when the seas and lakes were inhabited by testacea, of which a few only belonged to species now existing, a period which I have designated *Eocene*, as indicating the *dawn* of the present state of the animate creation. But although a small number only of the living species of animals were then in being, there are ample grounds for inferring that all the great classes of the animal kingdom, such as they now exist, were then fully represented. In regard to the testacea, indeed, it is no longer a matter of inference; for more than 1200 species of this class have been obtained from that small number of detached Eocene deposits which have hitherto been examined in Europe.

The celebrated Paris basin, the position of which was pointed out in the former part of this book (see wood-cut, Vol. III. p. 354.), first presents itself, and

seems to claim our chief attention when we examine the phenomena of this era. But in order the more easily to explain the peculiar nature and origin of that group, it will be desirable, first, to give a brief sketch of certain deposits of Central France, which afford many interesting points of analogy to that of Paris, both in organic remains and mineral composition, and where the original circumstances under which the strata were accumulated may more easily be discerned.

Auvergne.—The deposits alluded to, which I examined in the summer of 1828, in company with Mr. Murchison, are those of the lacustrine basins of Auvergne, Cantal, and Velay, and their sites may be seen in the annexed Map. They appear to be the monuments of ancient lakes, which may have resembled in geographical distribution some of those now existing in Switzerland, and may like them have occupied the depressions in a mountainous country, and have been each fed by one or more rivers and torrents. The country where they occur is almost entirely composed of granite and different varieties of granitic schist, with here and there a few patches of secondary strata much dislocated, and which have probably suffered great denudation. There are also some vast piles of volcanic matter (see the Map), the greater part of which is newer than the fresh-water strata, and is sometimes seen to rest upon them, whilst a small part has evidently been of contemporaneous origin. Of these igneous rocks I shall treat more particularly in the nineteenth chapter, and shall now speak only of the lacustrine beds.

The most northern of the fresh-water groups is situated in the valley-plain of the Allier, which lies within


PARIS BASIN
Fig 120.
Freshwater
Volcanic
Sancerre
Loire R.
Nevers
47°
Moulins
Loire R.
Monthucon
GRANITIC PLATFORM.
AUVERGNE.
FOREZ.
Allier R.
Gannat
Vichy
Roanne
46°
Monts Domes
Clermont
Montbrison
M.d'Or.
Issoire
Loire R.
Brioude
VELAY
Mauriac
Murat
Cantal
Le Puy
45°
Aurillac
Allier R.
Pradelles

the department of the Puy de Dome, being the tract which went formerly by the name of the Limagne d'Auvergne. It is inclosed by two parallel primitive ranges,—that of the Forèz, which divides the waters of the Loire and Allier, on the east; and that of the Monts Domes, which separates the Allier from the Sioule, on the west.* The average breadth of this tract is about twenty miles; and it is for the most part composed of nearly horizontal strata of sand, sandstone, calcareous marl, clay, and limestone, none of which observe a fixed and invariable order of superposition. The ancient borders of the lake wherein the fresh-water strata were accumulated, may generally be traced with precision, the granite and other ancient rocks rising up boldly from the level country. The precise junction, however, of the lacustrine and granitic beds is rarely seen, as a small valley usually intervenes between them. The fresh-water strata may sometimes be seen to retain their horizontality within a very slight distance of the border-rocks, while in some places they are inclined, and in a few instances vertical. The principal divisions into which the lacustrine series may be separated are the following:—1st, Sandstone, grit, and conglomerate, including red marl and red sandstone. 2dly, Green and white foliated marls. 3dly, Limestone or travertin, oolite. 4thly, Gypseous marls.

1. *a. Sandstone and conglomerate.*—Strata of sand and gravel, sometimes bound together into a solid rock, are found in great abundance around the confines of the lacustrine basin, containing, in different places, pebbles of all the ancient rocks of the adjoining ele-

* Scrope, Geology of Central France, p. 15.

vated country; namely, granite, gneiss, mica-schist, clay-slate, porphyry, and others. But the arenaceous strata do not form one continuous band around the margin of the basin, being rather disposed like the independent deltas which grow at the mouths of torrents along the borders of existing lakes.*

At Chamalieres, near Clermont, we have an example of one of these littoral groups of local extent, where the pebbly beds slope away from the granite as if they had formed a talus beneath the waters of the lake near the steep shore. A section of about fifty feet in vertical height has been laid open by a torrent, and the pebbles are seen to consist throughout of rounded and angular fragments of granite, quartz, primary slate, and red sandstone; but without any intermixture of those volcanic rocks which now abound in the neighbourhood. Partial layers of lignite and pieces of wood are found in these beds, but no shells; a fact which probably indicates that testacea could not live where the turbid waters of a stream were frequently hurrying down uprooted trees, together with sand and pebbles, or, that if they existed, they were triturated by the transported rocks.

There are other localities on the margin of the basin where quartzose grits are found, composed of white sand bound together by a siliceous cement.

Occasionally, when the grits rest on granite, as at Chamalieres before mentioned, and many other places, the separate crystals of quartz, mica, and felspar, of the disintegrated granite, are bound together again by the silex, so that the granite seems regenerated in a new and even more solid form; and thus so gradual a

* See book ii. chap. v.

passage may easily be traced between a crystalline rock and one of mechanical origin, that we can scarcely distinguish where one ends and the other begins.

In the Puy de Jussat, and the neighbouring hill of La Roche, are white quartzose grits, cemented by calcareous matter, which is sometimes so abundant as to form imbedded nodules. These sometimes constitute spheroidal concretions six feet in diameter, and pass into beds of solid limestone resembling the Italian travertins, or the deposits of mineral springs.

In the hills above mentioned, we have the advantage of seeing a section continuously exposed for about seven hundred feet in thickness. At the bottom are foliated marls, white and green, about four hundred feet thick; and above, resting on the marls, are the quartzose grits before mentioned, with the associated travertins. This section is close to the confines of the basin; so that the lake must here have been filled up near the shore with fine mud, before the coarse superincumbent sand was introduced. There are other cases where sand is seen below the marl.

1. *b. Red marl and sandstone.*—But the most remarkable of the arenaceous groups is one of red sandstone and red marl, which are identical in all their characters with the secondary *new red sandstone* and marl of England. In these secondary rocks, the red ground is sometimes variegated with light greenish spots, and the same may be seen in the tertiary formation of fresh-water origin at Coudes, on the Allier. The marls are sometimes of a purplish-red colour, as at Champheix, and are accompanied by a reddish limestone like the well-known "cornstone," which is associated with the old red sandstone of English geologists. The red sandstone and marl of Auvergne have evidently been

derived from the degradation of gneiss and mica-schist, which are seen *in situ* on the adjoining hills, decomposing into a soil very similar to the tertiary red sand and marl. We also find pebbles of gneiss, mica-schist, and quartz, in the coarser sandstones of this group, clearly pointing to the parent rocks from which the sand and marl were derived. The red beds, although destitute themselves of organic remains, pass upwards into strata containing Eocene fossils, and are certainly an integral part of the lacustrine formation.

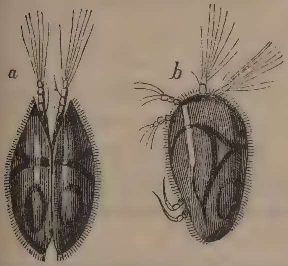
2. *Green and white foliated marls.*—A great portion of what we term clay in ordinary language consists of the same materials as sand, but the component parts are in a finer state of subdivision. The same primary rocks, therefore, of Auvergne which, by the partial degradation of their harder parts, gave rise to the quartzose grits and conglomerates before mentioned, would, by the reduction of the same materials into powder, and by the decomposition of their felspar, mica, and hornblende, produce aluminous clay; and, if a sufficient quantity of carbonate of lime was present, calcareous marl. This fine sediment would naturally be carried out to a greater distance from the shore, as are the various finer marls now deposited in Lake Superior.* And, as in the American lake, shingle and sand are annually amassed near the northern shores, so in Auvergne the grits and conglomerates before mentioned were evidently formed near the borders.

The entire thickness of these marls is unknown; but it certainly exceeds, in some places, seven hundred feet. They are for the most part either light-green or white, and usually calcareous. They are thinly fol-

* See Vol. I. p. 340.

iated,—a character which frequently arises from the innumerable thin plates or scales of that small animal called *Cypris;* a genus which comprises several species, of which some are recent, and may be seen swimming swiftly through the waters of our stagnant pools and ditches. The antennæ at the end of which are fine

Fig. 121.



Cypris unifasciata, a living species, greatly magnified.

a. Upper part. *b.* Side view of the same.

Fig. 122.

Cypris vidua, a living species greatly magnified.*

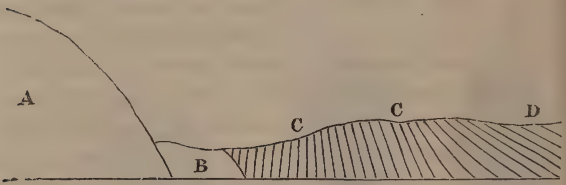
pencils of hair, are the principal organs for swimming, and are moved with great rapidity. This animal resides within two small valves not unlike those of a bivalve shell, and moults its integuments annually, which the conchiferous molluscs do not. This circumstance may partly explain the countless myriads of the shells of cypris which were shed in the Eocene lakes, so as to give rise to divisions in the marl as thin as paper, and that too in stratified masses several hundred feet thick. A more convincing proof of the tranquillity and clearness of the waters, and of the slow and gradual process by which the lake was filled up with fine mud, cannot be desired. But we may

* See Desmarest's Crustacea, plate 55.

easily suppose that, while this fine sediment was thrown down in the deep and central parts of the basin, gravel, sand, and rocky fragments were hurried into the lake near the shore, and formed the group described in the preceding section.

Not far from Clermont, the green marls, containing the cypris in abundance, approach to within a few yards

Fig. 123.



Vertical strata of marl near Clermont.

A. Granite. B. Space of sixty feet, in which no section is seen. C. Green marl, vertical and inclined. D. White marl.

of the granite which forms the borders of the basin. The annexed section occurs at Champradelle, in a small ravine north of La petite Baraque, and above the bridge.

The occurrence of these marls so near the ancient margin may be explained by considering that, at the bottom of the ancient lake, no coarse ingredients were deposited in spaces intermediate between the points where rivers and torrents entered, but finer mud only was drifted there by currents. The *verticality* of some of the beds in the above section bears testimony to considerable local disturbance subsequent to the deposition of the marls; but such inclined and vertical strata are very rare.

3. *Limestone, travertin, oolite.*—Both the preceding members of the lacustrine deposit, the marls and grits,

pass occasionally into limestone. Sometimes only concretionary nodules abound in them; but these, where there is an increase in the quantity of calcareous matter, unite, as already noticed (p. 161.), into regular beds.

On each side of the basin of the Limagne, both on the west at Gannat, and on the east at Vichy, a white oolitic limestone is quarried. At Vichy, the oolite resembles our Bath stone in appearance and beauty, and, like it, is soft when first taken from the quarry, but soon hardens on exposure to the air. At Gannat, the stone contains land-shells and bones of quadrupeds, resembling those of the Paris gypsum. In several places in the neighbourhood of Gannat, at Marculot among others, this stone is divided by layers of clay.

At Chadrat, in the hill of La Serre, the limestone is pisolitic, and in this and other respects resembles the travertin of Tivoli. It presents the same combination of a radiated and concentric structure, and the coats of the different spheroids have the same undulating surface.*

Indusial limestone. — There is another remarkable form of fresh-water limestone in Auvergne, called "indusial," from the cases, or *indusiæ,* of the larvæ of Phryganea, great heaps of which have been encrusted, as they lay, by carbonate of lime, and formed into a hard travertin. Several beds of this rock, either in continuous masses, or in concretionary nodules, are seen superimposed one upon another, with layers of marl interposed. We may often observe in our ponds some of the living species of this kind of insect, covered with

* See Fig. 9. Vol. I. p. 319.

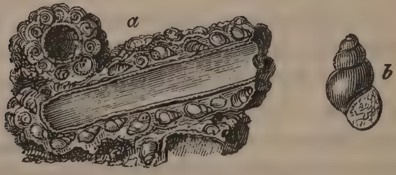
small fresh-water shells, which they have the power of fixing to the outside of their tubular cases, in order, probably, to give them weight and strength.

Fig. 124.

*Larva of recent Phryganea.**

The individual figured in the annexed cut, which belongs to a species very abundant in England, has happened to cover its case with shells of a small Planorbis. In the same manner, a large species which swarmed in the Eocene lakes of Auvergne was accustomed to attach to its dwelling the shells of a small spiral univalve of the genus *Paludina*. A hundred of these minute shells are sometimes seen arranged around one tube, part of the central cavity of which is often empty, the rest being filled up with thin concentric layers of travertin. The cases have been thrown together confusedly, and often lie, as in Fig. 125., at right angles one to the other. When we consider that ten or twelve tubes are packed within the compass of a cubic inch, and that some single strata of this

Fig. 125.



a. Indusial limestone of Auvergne.
b. Fossil Paludina magnified.

* I believe that the British specimen here figured is P. rhombica, Linn.

limestone are six feet thick, and may be traced over a considerable area, we may form some idea of the countless number of insects and mollusca which contributed their integuments and shells to compose this singularly constructed rock. It is unnecessary to suppose that the Phryganeæ lived on the spots where their cases are now found; they may have multiplied in the shallows near the margin of the lake, or in the streams by which it was fed, and their buoyant cases may have been drifted by a current far into the deep water.*

The calcareous strata of the Limagne, like the other members of this lacustrine formation, are for the most part horizontal, or inclined at a very slight angle, but instances of local dislocation are sometimes observable. At the town of Vichy, for example, in an ancient quarry behind the convent of Celestines, the strata dip at an angle of between thirty and forty degrees; and near the hot spring at the same place, the beds of limestone are seen, in one part of the section, inclined at an angle of eighty degrees, and in another vertical.

4. *Gypseous marls.* — More than fifty feet of thinly laminated gypseous marls, exactly resembling those in the hill of Montmartre, at Paris, are worked for gypsum at St. Romain, on the right bank of the Allier. They rest on a series of green cypriferous marls which alternate with grit, the united thickness of this inferior group being seen, in a vertical section on the banks of the river, to exceed 250 feet.

General arrangement and origin of the fresh-water formations of Auvergne. — The relations of the different groups above described cannot be learnt by the study

* For remarks on the floating of empty land shells by rivers, see p. 47., and Vol. III. p. 382.

of any one section, and the geologist who sets out with the expectation of finding a fixed order of succession may perhaps complain that the different parts of the basin give contradictory results. The arenaceous division (1. p. 159.), the marls (2. p. 162.), and the limestone (3. p. 164.), may all be seen in some places to alternate with each other; yet it can by no means be affirmed that there is no order of arrangement. The sands, sandstone, and conglomerate, constitute in general a littoral group; the foliated white and green marls, a contemporaneous central deposit; and the limestone is for the most part subordinate to the newer portions of both. The uppermost marls and sands are more calcareous than the lower; and we never meet with calcareous rocks covered by a considerable thickness of quartzose sand or green marl. From the resemblance of the Eocene limestones of Auvergne to the Italian travertins, we may conclude that they were derived from the waters of mineral springs, — such springs as now exist in Auvergne, and which, rising up through the granite, precipitate travertin. They are sometimes thermal, but this character is by no means constant.

It seems that, when the ancient lake of the Limagne first began to be filled with sediment, no volcanic action had yet produced lava and scoriæ on any part of the surface of Auvergne. No pebbles, therefore, of lava were transported into the lake, — no fragments of volcanic rocks imbedded in the conglomerate. But at a later period, when a considerable thickness of sandstone and marl had accumulated, eruptions broke out, and lava and tuff were deposited, at some spots, alternately with the lacustrine strata. Proofs of this will be given in the 19th chapter. It is

not improbable that cold and thermal springs, holding different mineral ingredients in solution, became more numerous during the successive convulsions attending this development of volcanic agency, and thus deposits of carbonate and sulphate of lime, silex, and other minerals, were produced. Hence these minerals predominate in the uppermost strata. The subterranean movements may then have continued until they altered the relative levels of the country and caused the waters of the lakes to be drained off, and the farther accumulation of regular fresh-water strata to cease. The occurrence of these convulsions anterior to the Miocene epoch, and their continuance during a succession of after-ages, may explain why no fresh-water formations more recent than the Eocene are now found in this country.

We may easily conceive a similar series of events to give rise to analogous results in any modern basin, such as that of Lake Superior, for example, where numerous rivers and torrents are carrying down the detritus of a chain of mountains into the lake. The transported materials must be arranged according to their size and weight, the coarser near the shore, the finer at a greater distance from land; but in the gravelly and sandy beds of Lake Superior no pebbles of modern volcanic rocks can be included, since there are none of these at present in the district. If igneous action should break out in that country and produce lava, scoriæ, and thermal springs, the deposition of gravel, sand, and marl might still continue as before; but in addition, there would then be an intermixture of volcanic gravel and tuff, and of rocks precipitated from the waters of mineral springs.

Although the fresh-water strata of theLimagne ap-

proach generally to a horizontal position, the proofs of local disturbance are sufficiently numerous and violent to allow us to suppose great changes of level since the Eocene period. We are unable to assign a northern barrier to the ancient lake, although we can still trace its limits to the east, west, and south, where they were formed of bold granitic eminences. But we need not be surprised at our inability to restore the physical geography of the country after so great a series of volcanic eruptions; for it is by no means improbable that one part of it may have been moved upwards bodily, while others remained at rest, or even suffered a movement of depression.

Puy en Velay.—In the department of the Haute Loire, a fresh-water formation, very analogous to that of Auvergne, is situated in the basin of the Loire, and is exposed in the valley in which stands the town of Le Puy. Since the deposition of the lacustrine strata, there have been so many volcanic eruptions in this country, and such immense quantities of lava and scoriæ have been poured out upon the surface, that the aqueous rocks are almost buried and concealed. But we are indebted to the researches of M. Bertrand de Doue, for having distinctly ascertained the succession of strata, and I have myself had opportunities of verifying his observations during a visit to Le Puy.

In this basin we find, as in Auvergne, two great divisions, consisting of grits and marls; the former composed of quartzose grit, in some places resembling granite, and of reddish and mottled sands and conglomerates. All these were evidently derived from the degradation of granitic rocks, and are very like the arenaceous group of the Limagne before described. They are almost confined to the borders of the basin,

and were evidently a littoral deposit. The other member of the formation, the *marls*, are more or less calcareous, and are associated with limestone and gypsum, which last exactly resembles that of Paris, and is worked for agricultural uses.

The analogy in the mineral character of the Velay and Paris basins is rendered more complete by the presence in both of silex in regular beds. In the limestone I found gyrogonites, or seeds of the Chara, of the same species as those most common in the Paris basin; and M. Bertrand de Doue has discovered the bones of several mammiferous animals of the same genera as those which characterize the basins of Auvergne and Paris.* The species of shells also of this formation are the same as those of Eocene formations in other parts of France.

The sand and conglomerate of the fresh-water basin of Velay are entirely free from volcanic pebbles, agreeing in this respect with the analogous group of the Limagne; but the fact is the more striking in Velay, because the masses of trachyte, clinkstone, and other igneous rocks now abounding in that country, have an aspect of very high antiquity, and constitute a most prominent feature in the geological structure of the district. Yet the non-intermixture of volcanic products with the lacustrine sediment, is just what we should expect when we have ascertained that the imbedded organic remains of those strata are Eocene; whereas the lavas belong in part, if not entirely, to the Miocene period.†

Cantal. — Near Aurillac, in Cantal, another series of fresh-water strata occurs, which resembles, in mi-

* Descrip. Géognos. des Env. du Puy en Velay, 1823.

† See p. 149., and chap. xix.

neral character and organic remains, those of Auvergne and Velay already described. The leading feature of this group, as distinguished from the two former, is the immense abundance of silex associated with the calcareous marls and limestone, which last constitute, like the limestone of Auvergne, an upper member of the fresh-water series.

The formations of the Cantal may be divided into two groups, the lower composed of gravel, sand, and clay, such as might have been derived from the wearing down and decomposition of the granitic schists of the surrounding country; the upper system consisting of siliceous and calcareous marls, contains subordinately gypsum, silex, and limestone — deposits such as the waters of springs charged with carbonate and sulphate of lime, and with silica, may have produced.

Fresh-water limestone and flints resembling chalk. — To the English geologist, the most interesting feature in the Cantal is the resemblance of the fresh-water limestone, and its accompanying flint, to our upper chalk; a resemblance which (like that of the red sandstone of Auvergne to our secondary "new red") is the more important, as being calculated to put the student upon his guard against relying too implicitly on lithological characters as tests of the relative ages of rocks. When we approach Aurillac from the west, we pass over great heathy plains, where the sterile mica-schist is barely covered with vegetation. Near Ytrac, and between La Capelle and Viscamp, we find the surface strewed over with loose broken flints, some of them black in the interior, but with a white external coating; others stained with tints of yellow and red, and in appearance precisely like the flint gravel of our chalk districts. When heaps of this gravel have thus

announced our approach to a new formation, we arrive at length at the escarpment of the lacustrine beds. At the bottom of the hill which rises before us, we see strata of clay and sand resting on mica-schist; and above, in the quarries of Belbet, Leybros, and Bruel, a white limestone, in horizontal strata, the surface of which has been hollowed out into irregular furrows, since filled up with broken flint, marl, and dark vegetable mould. In these cavities we recognize an exact counterpart to those which are so numerous on the furrowed surface of our own white chalk. Advancing from these quarries, along a road made of the white limestone, which reflects as glaring a light in the sun, as do our roads composed of chalk, we reach, at length, in the neighbourhood of Aurillac, hills of limestone and calcareous marl, in horizontal strata, separated in some places by regular layers of flint in nodules, the coating of each nodule being of an opaque white colour, like the exterior of the flinty nodules of our chalk. This hard white substance has been ascertained in England to consist, in some instances, wholly of siliceous matter, and sometimes to contain a small admixture of carbonate of lime*, and the analysis of the similar rocks in the Cantal would probably give the same results. The Aurillac flints have precisely the appearance of having separated from their matrix after the siliceous and calcareous matter had been blended together. The calcareous marl sometimes occupies small sinuous cavities in the flint; and the siliceous nodule, when detached, is often as irregular in form as those found in our chalk.

By what means, then, can the geologist at once

* Phillips, Geol. Trans. First Series vol. v. p. 22.—Outlines of Geology, p. 95.

decide that the limestone and silex of Aurillac are referrible to an epoch entirely distinct from that of the English chalk? It is not by reference to position; for we can merely say of the lacustrine beds, as we should have been able to declare of the true chalk had it been present, that they overlie the granitic rocks of this part of France. It is from the organic remains only that we are able to pronounce the formation to belong to the Eocene tertiary period. Instead of the marine Alcyonia of our cretaceous system, the silicified seed-vessels of the Chara, a plant which grows at the bottom of lakes, abound in the flints of Aurillac, both in those which are *in situ* and those forming the gravel. Instead of the Echini and marine testacea of the chalk, we find in these marls and limestones the shells of the Planorbis, and other lacustrine testacea, all of them, like the gyrogonites, agreeing specifically with species of the Eocene type.

Proofs of the gradual deposition of marl. — Some sections of the foliated marls in the valley of the Cer, near Aurillac, attest, in the most unequivocal manner, the extreme slowness with which the materials of the lacustrine series were amassed. In the hill of Barrat, for example, we find an assemblage of calcareous and siliceous marls, in which, for a depth of at least sixty feet, the layers are so thin that thirty are sometimes contained in the thickness of an inch; and when they are separated we see preserved in every one of them the flattened stems of Charæ, or other plants, or sometimes myriads of small *paludinæ* and other fresh-water shells. These minute foliations of the marl resemble precisely some of the recent laminated beds of the Scotch marl lakes, and may be compared to the pages of a book, each containing a history of a certain period

of the past. The different layers may be grouped together in beds from a foot to a foot and a half in thickness, which are distinguished by differences of composition and colour, the tints being white, green, and brown. Occasionally there is a parting layer of pure flint, or of black carbonaceous vegetable matter, about an inch thick, or of white pulverulent marl. We find several hills in the neighbourhood of Aurillac composed of such materials for the height of more than 200 feet from their base, the whole sometimes covered by rocky currents of trachytic or basaltic lava.*

Thus wonderfully minute are the separate parts of which some of the most massive geological monuments are made up! When we desire to classify, it is necessary to contemplate entire groups of strata in the aggregate; but if we wish to understand the mode of their formation, and to explain their origin, we must think only of the minute subdivisions of which each mass is composed. We must bear in mind how many thin leaf-like seams of matter, each containing the remains of myriads of testacea and plants, frequently enter into the composition of a single stratum, and how vast a succession of these strata unite to form a single group! We must remember also, that volcanos like the Plomb du Cantal, which rises in the immediate neighbourhood of Aurillac, are themselves equally the result of successive accumulation, consisting of reiterated flows of lava and showers of scoriæ; and I have shown, when treating of the high antiquity of Etna, how many dis-

* Lyell and Murchison, sur les Dépôts Lacust. Tertiaires du Cantal, &c. Ann. des Sci. Nat., Oct. 1829.

tinct lava-currents and heaps of ejected substances are required to make up one of the numerous conical envelopes whereof a volcano is composed. — Lastly, we must not forget that continents and mountain-chains, colossal as are their dimensions, are nothing more than an assemblage of many such igneous and aqueous groups, formed in succession during an indefinite lapse of ages, and superimposed upon each other.

CHAPTER XVIII.

EOCENE FORMATIONS — PARIS BASIN.

Marine Eocene strata — Paris basin how far analogous to deposits of Central France — Connexion of Auvergne and Paris basins — Groups in Paris basin — Observations of M. C. Prevost — Contemporaneous marine and fresh-water strata — Abundance of Cerithia (p.182.) — Upper marine formation — All the Parisian groups Eocene — Microscopic shells (p.189.) — Bones of quadrupeds in gypsum — Strata with and without organic remains alternating — Extent of our knowledge of the physical geography, fauna, and flora of the Eocene period — Concluding remarks.

The geologist who has studied the lacustrine formations described in the last chapter cannot enter the tract usually termed "the Paris Basin" without immediately recognizing a great variety of rocks with which his eye has already become familiar. The green and white marls of Auvergne, Cantal, and Velay, again present themselves, together with limestones and quartzose grits, siliceous and gypseous marls, nodules and layers of flint, and saccharoid gypsum; lastly, in addition to all this identity of mineral character, he finds an assemblage of the same species of fossil animals and plants.

When we consider the geographical proximity of the two districts, we are the more prepared to ascribe this correspondence in the mineral composition of these groups to a combination of similar circumstances

at the same era. From the map (Fig. 120. p. 158.) in the last chapter, it will be seen that the united waters of the Allier and Loire, after descending from the valleys occupied by the fresh-water formations of Central France, flow on till they reach the southern extremity of what is called the Paris basin. M. Omalius d'Halloy long ago suggested the very natural idea that there existed formerly a chain of lakes, reaching from the highest part of the central mountain-group of France, and terminating in the basin of Paris, which he supposes was at that time an arm of the sea.

Notwithstanding the great changes which the physical geography of this part of France must since have undergone, we may easily conceive that many of the principal features in the configuration of the country may have remained unchanged, or but slightly modified. Hills of volcanic matter have indeed been formed since the Eocene formations were accumulated, and the levels of large tracts have been altered in relation to the sea; lakes have been drained, and a gulf of the sea turned into dry land, but many of the reciprocal relations of the different parts of the surface may still remain the same. The waters which flowed from the granitic heights into the Eocene lakes may now descend in the same manner through valleys once the basins of those lakes. Let us, for illustration, suppose the great Canadian lakes, and the gulf into which their waters are discharged, to be elevated and laid dry by subterranean movements. The whole hydrographical basin of the St. Lawrence might be upraised during these convulsions, yet that river might continue, even after so extraordinary a revolution, to drain the same elevated regions, and might still convey its waters in the same direction from the interior of the

continent to the Atlantic. Instead of traversing the lakes, it would hold its course through deposits of lacustrine sand and shelly marl, such as we know to be now forming in Lakes Superior and Erie; and these fresh-water strata would occupy the site and bear testimony to the pristine existence of the lakes. Marine strata may also be brought into view in the space where an inlet of the sea, like the estuary of the St. Lawrence, had once received the continental waters; and in such formations we might discover shells of lacustrine and fluviatile species intermingled with marine testacea and zoophytes.

Subdivisions of strata in the Paris basin.—The area which has been called the Paris basin is about 180 miles in its greatest length from north-east to south-west, and about ninety miles from east to west. This space may be described as a depression in the chalk (see Fig. 62. Vol. III. p. 354.), which has been filled up by alternating groups of marine and freshwater strata. MM. Cuvier and Brongniart attempted in 1811 to distinguish five different formations, and to arrange them in the following order, beginning with the lowest:—

1. First fresh-water formation	Plastic clay. Lignite. First sandstone.
2. First marine formation	Calcaire grossier.
3. Second fresh-water formation	Siliceous limestone. Gypsum, with bones of animals. Fresh-water marls.
4. Second marine formation	Gypseous marine marls. Upper marine sands and sandstones. Upper marine marls and limestones.
5. Third fresh-water formation	Siliceous millstone, without shells. Siliceous millstone, with shells. Upper fresh-water marls.

These formations were supposed to have been deposited in succession upon the chalk; and it was imagined that the waters of the ocean had been by turns admitted into and excluded from the same region. But the subsequent investigations of several geologists, especially of M. Constant Prevost *, have led to great modifications in the theoretical views entertained respecting the order in which the several groups were formed; and it now appears that the formations Nos. 1, 2, and 3. of the table of MM. Cuvier and Brongniart, instead of having originated one after the other, are divisible into four nearly contemporaneous groups.

Superposition of different formations in the Paris basin. — A comparison of the two accompanying diagrams will show at a glance the different relations

Fig. 126.

M. Alex. Brongniart.

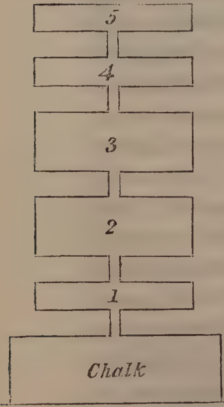
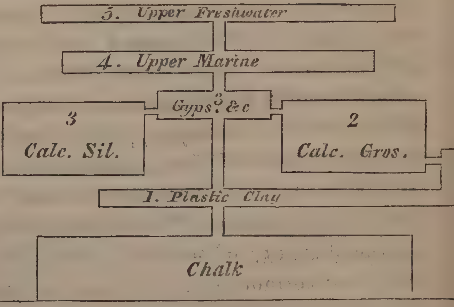


Fig. 127.

M. Constant Prevost.



* Bulletin des Sci. de la Soc. Philom., May, 1825, p. 74.

which the several sets of strata bear to each other, according to the original as well as the more modern classification. I shall now proceed to lay before the reader a brief sketch of the several sets of strata referred to in the above systems.

Immediately upon the chalk a layer of broken chalk flints, often cemented into a breccia by siliceous sand, is very commonly found. These flints probably indicate the action of the sea upon reefs of chalk when a portion of that rock had emerged, and before the regular tertiary beds were superimposed. To this partial layer no reference is made in the annexed sections.

Plastic clay and sand. — Upon this flinty stratum, or, if it be wanting, upon the chalk itself, rests frequently a deposit of clay and lignite (No. 1. of the above tables). It includes the remains of fresh-water shells and drift-wood, and was, at first regarded as a proof that the Paris basin had originally been filled with fresh water. But it has since been shown that this group is not only of very partial extent, but is by no means restricted to a fixed place in the series; for it alternates with the marine calcaire grossier (No. 2. of the tables), and is repeated in the very middle of that limestone at Veaugirard, Bagneux, and other places, where the same Planorbes, Paludinæ, and Limneæ occur.* M. Desnoyers pointed out to me a section in the suburbs of Paris, laid open in 1829, where a similar intercalation was seen in a still higher part of the calcaire grossier. These observations relieve us from the difficulty of seeking a cause why vegetable matter, and certain species of fresh-water shells and a

* Prevost, Sur les Submersions Itératives, &c. Mém. de la Soc. d'Hist. Nat. de Paris, tome iv. p. 74.

particular kind of clay, were at first introduced into the basin, and why the same space was subsequently usurped by the sea. A minute examination of the phenomena leads us simply to infer, that a river charged with argillaceous sediment entered a bay of the sea and drifted into it, from time to time, fresh-water shells and wood.

Calcaire grossier.— The calcaire grossier above alluded to, is a coarse limestone, often passing into sand, such as may perhaps have been in part derived from the aqueous degradation of a chalk country. It contains by far the greater number of the fossil shells which characterize the Paris basin. No less than 400 distinct species have been procured from a single spot near Grignon. They are imbedded in a calcareous sand, chiefly formed of comminuted shells, in which, nevertheless, individuals in a perfect state of preservation, both of marine, terrestrial, and fresh-water species, are mingled together, and were evidently transported from a distance. Some of the marine shells may have lived on the spot; but the Cyclostoma and Limnea must have been brought thither by rivers and currents, and the quantity of triturated shells implies considerable movement in the waters.

Nothing is more striking in this assemblage of fossil testacea than the great proportion of species referrible to the genus Cerithium. (See fig. 128.) There occur no less than one hundred and thirty-seven species of this genus in the Paris basin, and almost all of them in the calcaire grossier. Now the living testacea of this genus inhabit the sea near the mouths of rivers, where the waters are brackish, so that their abundance in the marine strata of the Paris basin is in perfect harmony with the hypothesis before advanced

Fig. 128.

*Cerithium cinctum.**

that a river flowed into the gulf, and gave rise to the beds of clay and lignite before mentioned. But there are ample data for inferring that the gulf was supplied with fresh water by more than one river; for while the calcaire grossier occupies the northern part of the Paris basin, another contemporaneous deposit, of fresh-water origin, appears at the southern extremity.

Calcaire siliceux.—This group (No. 3. of the foregoing tables) is a compact siliceous limestone, which resembles a precipitate from the waters of mineral springs. It is often traversed by small empty sinuous cavities; is for the most part devoid of organic remains, but in some places contains fresh-water and land species, and never any marine fossils. The siliceous limestone and the calcaire grossier occupy distinct parts of the basin, the one attaining its fullest development in those places where the other is of slight thickness. They also alternate with each other towards the centre of the basin, as at Sergy and Osny; and there are even points where the two rocks are so blended together, that portions of each may be seen in hand specimens. Thus in the same bed, at Triel, we have the compact fresh-water limestone, characterized by its Limneæ, mingled with the coarse marine limestone through which the small multilocular shell, called milliolite, is dispersed in countless numbers. These microscopic testacea are also accompanied by Cerithia and other shells of the calcaire grossier. It is very extraordinary that in this instance both kinds of sediment must have been thrown down together on the same spot, and each has still retained its own peculiar organic remains.

* This species is found also in the Paris and London basins.

This limestone was pointed out to me by M. Prevost, both *in situ* at Triel, and in hand specimens in his cabinet.

These facts lead irresistibly to the conclusion, that while to the north, where the bay was probably open to the sea, a marine limestone was formed, another deposit of fresh-water origin was introduced to the southward, or at the head of the bay; for it appears that during the Eocene period, as now, the ocean was to the north; and the continent, where the great lakes existed, to the south. From that southern region we may suppose a body of fresh water to have descended charged with carbonate of lime and silica, the water being perhaps in sufficient volume to convert the upper end of the bay into fresh water, like some of the gulfs of the Baltic.

Gypsum and marls. — The next group to be considered is the gypsum, and the white and green marls, subdivisions of No. 3. of the table of Cuvier and Brongniart. These were once supposed to be entirely subsequent in origin to the two groups already considered; but M. Prevost has pointed out that in some localities they alternate repeatedly with the calcaire siliceux, and in others with some of the upper members of the calcaire grossier. The gypsum, with its associated marl and limestone, is in greatest force towards the centre of the basin, where the two groups before mentioned are less fully developed; and M. Prevost infers, that while those two principal deposits were gradually in progress, the one towards the north, and the other towards the south, a river descending from the east may have brought down the gypseous and marly sediment.

It must be admitted, as highly probable, that a bay

or narrow sea, 180 miles in length, would receive, at more points than one, the waters of the adjoining continent; at the same time I may observe, that if the gypsum and associated green and white marls of Montmartre were derived from a hydrographical basin distinct from that of the southern chain of lakes before adverted to, this basin must nevertheless have been placed under circumstances extremely similar; for the identity of the rocks of Velay and Auvergne with the freshwater group of Montmartre, is such as can scarcely be appreciated by geologists who have not carefully examined the structure of both these countries.

Some readers may think that the view above given of the arrangement of four different sets of strata in the Paris basin is far more obscure and complicated than that first presented to them in the system of MM. Cuvier and Brongniart. Undoubtedly the relations of the several groups are less simple than the first observers supposed, being much more analogous to those before described in the lacustrine deposits of Central France. The simultaneous deposition of two or more groups of strata in one basin, some of them fresh-water and others marine, must always produce very complex results; but in proportion as it is more difficult in these cases to discover any fixed order of superposition in the associated mineral masses, so also is it more easy to explain the manner of their origin and to reconcile their relations to the agency of known causes. Instead of the successive irruptions and retreats of the sea, and changes in the chemical nature of the fluid and other speculations of the earlier geologists, we are now simply called upon to imagine a gulf, into one extremity of which the sea entered, and at the other a large river, while other streams may

have flowed in at different points, whereby an indefinite number of alternations of marine and freshwater beds would be occasioned.

Second or Upper marine group.— The next group, called the second or upper marine formation (No. 4. of the tables), consists in its lower division of green marls, which alternate with the fresh-water beds of gypsum and marl last described. Above this division the products of the sea exclusively predominate, the beds being chiefly formed of micaceous and quartzose sand, eighty feet or more in thickness, surmounted by beds of sandstone, with scarcely any limestone. The summits of a great many platforms and hills in the Paris basin consist of this upper marine series.

I fully agree with M. C. Prevost that the alternation of the various marine and fresh-water formations before described admit of a satisfactory explanation without supposing different retreats and subsequent returns of the sea; yet I think that a subsidence of the soil would best account for the position of these upper marine sands. Oscillations of level may have occurred, in consequence of which the sea and a river may have prevailed each in their turn for a time, until at length, by a more considerable sinking down of part of the basin, a tract previously occupied by fresh water was converted into a sea of moderate depth.

In one part of the Paris basin there are decisive proofs that during the Eocene period, and before the upper marine sand was formed, parts of the calcaire grossier were exposed to the action of denuding causes. At Valmondois, for example, a deposit of the upper marine sandstone is found, in which rolled blocks of the calcaire grossier with its peculiar fossils, and fragments of a limestone resembling the calcaire

siliceux, occur.* These calcareous boulders are rolled and pierced by perforating shells belonging to no less than fifteen distinct species. Both the blocks and many worn shells washed out from the calcaire grossier, are found mingled with the ordinary fossils of the upper marine sand.

We have seen that the same earthquake in Cutch could raise one part of the delta of the Indus and depress another, and cause the river to cut a passage through the upraised strata, and carry down the materials removed from the new channel into the sea. All these changes, therefore, might happen within a short interval of time between the deposition of two sets of strata in the same delta.†

It is not improbable, then, that the same convulsions which caused one part of the Paris basin to sink down, so as to let in the sea upon the area previously covered by gypsum and fresh-water marl, may have lifted up the calcaire grossier and the siliceous limestone, so that they might be acted upon by the waves, and fragments of them swept down into the contiguous sea, there to be drilled by boring testacea.

It is observed that the older marine formation at Laon is now raised three hundred metres or nearly one thousand feet above the sea, whereas the upper marine sands never attain half that elevation. Such may possibly have been the relative altitude of the two groups when the newest of them was deposited.

Third fresh-water formation.—We have still to con-

* M. Deshayes, Mémoires de la Soc. d'Hist. Nat. de Paris, tom. i. p. 243. The sandstone is there called, by mistake, grès marin *inférieur,* instead of *supérieur,* to which last the author has since ascertained it to belong.

† Vol. II. p. 237.

sider another formation, the third fresh-water group (No. 5. of the preceding tables). It consists of marls interstratified with beds of flint and layers of flinty nodules. One set of siliceous layers is destitute of organic remains, the other replete with them.

Gyrogonites, or fossil seed-vessels of charæ, are found abundantly in these strata, and all the animal and vegetable remains agree well with the hypothesis, that after the gulf or estuary had been silted up with the sand of the upper marine formation, a great number of marshes and shallow lakes existed, like those which frequently overspread the newest parts of a delta. These lakes were fed by rivers or springs which contained, in chemical solution or mechanical suspension, such kinds of sediment as we have already seen to have been deposited in the lakes of Central France during the Eocene period.

The Parisian groups all Eocene.—Having now given a rapid sketch of the different groups of the Paris basin, I may observe generally that they all belong to the Eocene epoch, although the entire series must doubtless have required an immense lapse of ages for its accumulation. The shells of the different fresh-water groups, constituting at once some of the lowest and uppermost members of the series, are nearly all referrible to the same species, and the discordance between the marine testacea of the calcaire grossier and the upper marine sands is very inconsiderable.

A curious observation has been made by M. Deshayes, in reference to the changes which one species, the *Cardium porulosum*, has undergone during the long period of its existence in the Paris basin. Different varieties of this cardium are characteristic of different strata. .In the older sand of the Soissonais (a marine

MICROSCOPIC FOSSIL SHELLS. EOCENE TERTIARY PERIOD.

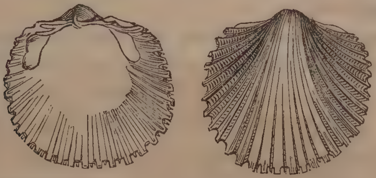
PARIS BASIN.

1. 2. 3. 4. — Triloculina inflata. Desh. — 5. 6. 7. 8. Quinqueloculina striata. Desh.
9. 10. 11. Calcarina rarispina. Desh. — 12. 13. 14. Clavulina corrugata. Desh.
15. 16. 17. 18. Spirolina stenostoma. Desh.

London, Published by John Murray, Decr. 1831.

formation underlying the regular beds of the calcaire grossier), this shell acquires but a small volume, and

Fig. 129.



Cardium porulosum. Paris and London basins.

has many peculiarities, which disappear in the lowest beds of the calcaire grossier. In these the shell attains its full size, and many peculiarities of form, which are again modified in the uppermost beds of the calcaire grossier; and these last characters are preserved throughout the whole of the "upper marine" series.*

Miliolite limestone and microscopic shells.—In some parts of the calcaire grossier round Paris, certain beds occur of a stone used in building, and called by the French geologists *miliolite limestone.* It is almost entirely made up of millions of small shells of the size of minute grains of sand, which all belong to the same class, but are of distinct species from those found in the Older Pliocene beds of Italy. These minute fossil bodies belong to the order *Cephalopoda,* the animals of which are more free in their movements, and more advanced in their organization, than any other mollusca. The multilocular cephalopods have been separated, by D'Orbigny into two subdivisions: first, those having a siphon or internal tube connecting the different chambers, such as the nautilus and ammonite; and, secondly, those without a siphon, to which the microscopic species now under consideration belong. They

* Coquilles caractérist. des Terrains, 1831.

are often in an excellent state of preservation, and their forms are singularly different from those of the larger testacea.

A plate of some of these is given, from unpublished drawings by M. Deshayes, who has carefully selected the most remarkable types of form. The *natural size* of each species figured (Plate XIII.) is indicated by such minute points, that it is necessary to call attention to them, as they might otherwise be overlooked. It should also be mentioned that the genus miliolite of Lamarck has since been subdivided into several genera, among which are the Triloculina and Quinqueloculina figured in the plate (Pl. XIII.).

Characteristic shells.—The species of shells figured in the annexed plate are common in the Paris basin, and may be considered as characteristic of the Eocene period generally. They appear as yet to be exclusively confined to deposits of that period, and are for the most part abundant in them wherever they have been attentively studied. (Pl. XIV.)

Bones of quadrupeds in gypsum.—I have already considered the position of the gypsum which occurs in the form of a saccharoid rock in the hill of Montmartre at Paris, and other central parts of the basin. At the base of that hill it is seen distinctly to alternate with soft marly beds of the calcaire grossier, in which cerithia and other marine shells occur. But the great mass of gypsum may be considered as a purely freshwater deposit, containing land and fluviatile shells, together with fragments of palm-wood, and great numbers of skeletons of quadrupeds and birds, an assemblage of organic remains which has given great celebrity to the Paris basin. The bones of fresh-water fish, also, and of crocodiles, and many land and fluvia-

Plate XIV

1 Voluta costaria. Lamk. _ 2 Pleurotoma clavicularis _ 3 Cassidaria carinata Lamk.
4 Nerita tricarinata. Lamk. _ 5 Calyptraea trochiformis. Lamk. _ 6 Turritella imbricataria Lamk. _ 7 Voluta digitalina Lamk. _ 8. Natica epiglottina Lamk. _
9 Solarium canaliculatum. Lamk. _ 10 Cardita planicosta Desh.

tile reptiles, occur in this rock. The skeletons of mammalia are usually isolated, often entire, the most delicate extremities being preserved, as if the carcasses, clothed with their flesh and skin, had been floated down soon after death, and while they were still swoln by the gases generated by their first decomposition. The few accompanying shells are of those light kinds which frequently float on the surface of rivers together with wood.

M. Prevost has therefore suggested that a river may have swept away the bodies of animals, and the plants which lived on its borders, or in the lakes which it traversed, and may have carried them down into the centre of the gulf into which flowed the waters impregnated with sulphate of lime. We know that the Fiume Salso in Sicily enters the sea so charged with various salts that the thirsty cattle refuse to drink of it. A stream of sulphureous water, as white as milk, descends into the sea from the volcanic mountain of Idienne, on the east of Java; and a great body of hot water, charged with sulphuric acid, rushed down from the same volcano on one occasion, and inundated a large tract of country, destroying, by its noxious properties, all the vegetation.* In like manner the Pusanibio, or "Vinegar River," of Colombia, which rises at the foot of Puracé, an extinct volcano 7500 feet above the level of the sea, is strongly impregnated with sulphuric and muriatic acids, and with oxide of iron. We may easily suppose the waters of such streams to have properties noxious to marine animals,

* Leyde Magaz. voor Wetensch Konst en Lett., partie v. cahier i. p. 71. Cited by Rozet, Journ. de Géologie, tom. i. p. 43.

and in this manner the entire absence of marine remains in the ossiferous gypsum may be explained.*

There are no pebbles or coarse sand in the gypsum; a circumstance which agrees well with the hypothesis that these beds were precipitated from water holding sulphate of lime in solution, and floating the remains of different animals. The bones of land quadrupeds, however, are not confined entirely to the fresh-water formation to which the gypsum belongs; for the remains of a Palæotherium, together with some fresh-water shells, have been found in a marine stratum belonging to the calcaire grossier at Beauchamp.

In the gypsum the remains of about fifty species of quadrupeds have been found, all extinct, and nearly four-fifths of them belonging to a division of the order Pachydermata, which is now represented by only four living species; namely, three tapirs and the daman of the Cape. With them a few carnivorous animals are associated, among which are a species of fox and gennet. Of the Rodentia, a dormouse and a squirrel; of the Insectivora, a bat; and of the Marsupialia (an order now confined to America, Australia, and some contiguous islands), an opossum, have been discovered.

Of birds, about ten species have been ascertained, the skeletons of some of which are entire. None of them are referrible to existing species.† The same remark applies to the fish, according to MM. Cuvier and Agassiz, as also to the reptiles. Among the last are crocodiles and tortoises of the genera Emys and Trionix.

The tribe of land quadrupeds most abundant in this

* M. C. Prevost, Submersions Itératives, &c. Note 23.

† Cuvier, Oss. Foss., tom. iii. p. 255.

formation is such as now inhabits alluvial plains and marshes and the banks of rivers and lakes, a class most exposed to suffer by river inundations. Whether the disproportion of carnivorous animals can be ascribed to this cause, or whether they were comparatively small in number and dimensions, as in the indigenous fauna of Australia, when first known to Europeans, is a point on which it would be rash perhaps to offer an opinion in the present state of our knowledge.

We have no reason to be surprised that all the species of vertebrated animals hitherto observed are extinct, when we recollect that out of 1122 species of fossil testacea obtained from the Paris basin, thirty-eight only can be identified with species now living. I have more than once adverted to the fact, that extinct mammalia are often found associated with assemblages of *recent* shells, a fact from which I have inferred the inferior duration of species of the mammalia as compared with the testacea; and it is not improbable that the higher order of animals in general may more readily become extinct than the marine mollusca. Some of the thirty-eight species of testacea above alluded to, as having survived from the Eocene period to our own times, have now a wide geographical range, as, for example, *Lucina divaricata* *, and are therefore fitted to exist under a great variety of circumstances. On the other hand, the great proportion of the Eocene marine testacea which have become extinct sufficiently demonstrates that the loss of species has been due to general laws; and that a sudden catastrophe, such as the invasion of a whole continent by the sea—a cause which could annihilate only the terrestrial and fresh-

* See Fig. 65. Vol. III. p. 394.

water tribes, is an hypothesis wholly inadequate to account for the phenomenon.

Strata with and without organic remains alternating. — Between the gypsum of the Paris basin and the upper marine sands a thin bed of oysters is found, which is spread over a remarkably wide area. From the manner in which they lie, it is inferred that they did not grow on the spot, but that some current swept them away from a bed of oysters formed in some other part of the bay. The strata of sand which immediately repose on the oyster-bed are quite destitute of organic remains; and nothing is more common in the Paris basin and in other formations, than alternations of shelly beds with others entirely devoid of them. The temporary extinction and renewal of animal life at successive periods have been inferred from such phenomena, which may nevertheless be explained, as M. Prevost justly remarks, without appealing to any such extraordinary revolutions in the state of the animate creation. A current one day scoops out a channel in a bed of shelly sand and mud, and the next day, by a slight alteration of its course, ceases to prey upon the same bank. It may then become charged with sand unmixed with shells, derived from some dune, or brought down by a river. In the course of ages an indefinite number of transitions from shelly strata to those without shells may thus be caused.

Concluding remarks.—It will be seen by our observations on Auvergne and other parts of Central France, and on the district round Paris, that geologists have already gained a considerable insight into the state of the physical geography of part of Europe during the Eocene period. We can point to some districts where lakes and rivers then existed, and to the site of

some of the lands encircling those lakes, and to the position of a great bay of the sea, into which their surplus waters were discharged. We can also show, as I shall endeavour to explain in the next chapter, the points where some volcanic eruptions took place. Much information has been acquired respecting the quadrupeds which inhabited the land at that period, and concerning the reptiles, fishes, and testacea which swarmed in the waters of lakes and rivers; and we have a collection of the marine Eocene shells more complete than has yet been obtained from any existing sea of equal extent in Europe. Nor are the contemporary fossil plants altogether unknown to us, which, like the animals, are of extinct species, and indicate a warmer climate than that now prevailing in the same latitudes.

When we reflect on the tranquil state of the earth, implied by some of the lacustrine and marine deposits of this age, and consider the fulness of all the different classes of the animal kingdom, as deduced from the study of the fossil remains, we are naturally led to conclude, that the earth was at that period in a perfectly settled state, and already fitted for the habitation of man.

The heat of European latitudes during the Eocene period does not seem to have been superior, if equal, to that now experienced between the tropics; some *living* species of molluscous animals, both of the land, the lake, and the sea, existed when the strata of the Paris basin were formed; and the contrast in the organization of the various tribes of Eocene animals, when compared to those now co-existing with man, although striking, is not, perhaps, so great as between the living Australian and European types. At the

same time, we must be fully aware that we cannot reason with any confidence on the capability of our own, or any other contemporary species, to exist under circumstances so different as those which might be caused by an entirely new distribution of land and sea; and we know that in the earlier tertiary periods the physical geography of the northern hemisphere was very distinct. Our inability to account for the atmospheric and other latent causes, which often give rise to the most destructive epidemics, proves the extent of our ignorance of the entire assemblage of conditions requisite for the existence of any one species on the globe.

CHAPTER XIX.

EOCENE VOLCANIC ROCKS.

Volcanic rocks of Auvergne — Eruptions at successive periods — Mont Dor an extinct volcano — Velay — Plomb du Cantal, (p. 204.) — Train of minor volcanos stretching from Auvergne to the Vivarais — Monts Domes — Ravines excavated through lava — Alluviums of distinct ages (p. 209.) — Age of more modern lavas of Central France — No eruption during the historical era — Division of volcanos into ante-diluvian and post-diluvian inadmissible — Theories respecting the effects of the Flood considered (p. 214.) — Recapitulation.

In treating of the lacustrine deposits of Central France, in the seventeenth chapter, I omitted, in order to avoid confusion, all details respecting the associated volcanic rocks, to which I now recall the reader's attention. (See the Map, p. 158.)

It was stated that, in the arenaceous and pebbly group of the lacustrine basins of Auvergne, Cantal, and Velay, no volcanic pebbles had ever been detected, although massive piles of igneous rocks are now found in the immediate vicinity. As this observation has been confirmed by minute research, we are warranted in inferring that the volcanic eruptions had not commenced when the older subdivisions of the fresh-water groups originated.

In Cantal and Velay no decisive proofs have yet been brought to light that any of the igneous outbursts happened during the deposition of the fresh-

water strata; but there can be no doubt that in Auvergne some volcanic explosions took place before the drainage of the lakes, and at a time when the Eocene species of animals and plants still flourished. I shall first advert to these proofs, as relating to the history of the period under consideration, and shall then proceed to show that there are in the same country volcanic rocks of much newer date, some of which appear to be referrible to the Miocene era.

Volcanic rocks associated with lacustrine in Auvergne. — The first locality to which I shall call the reader's attention is Pont du Chateau, near Clermont, which spot, as well as all the others in Auvergne, mentioned in this chapter, I examined, in company with Mr. Murchison, in 1828. The section at this place is seen in a precipice on the right bank of the river Allier. Here beds of volcanic tuff alternate with a fresh-water limestone, which is in some places pure, but in others spotted with fragments of volcanic matter, as if it were deposited while showers of sand and scoriæ were projected from a neighbouring vent.* This limestone contains the *Helix Ramondi* and other shells of Eocene species. It is immaterial to the present argument whether the volcanic sand was showered down from above, or drifted to the spot by a river; for the latter opinion must presuppose the country to have been covered with volcanic ejections during the Eocene period.

Another example occurs in the Puy de Marmont, near Veyres, where a fresh-water marl alternates with volcanic tuff containing Eocene shells. The tuff or breccia in this locality is precisely such as is known to

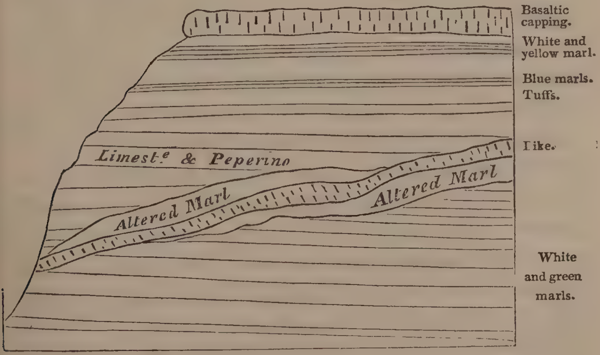
* See Scrope's Central France, p. 21.

result from volcanic ashes falling into water, and subsiding together with ejected fragments of marl and other stratified rocks. These tuffs and marls are highly inclined, and traversed by a thick vein of basalt, which, as it rises in the hill, divides into two branches.

Gergovia. — The hill of Gergovia, near Clermont, affords a third example. I agree with MM. Dufrénoy d Jobert that there is no alternation here of lava and fresh-water strata, in the manner supposed by some other observers *; but the position and contents of some of the tuffs prove them to have been derived from volcanic eruptions which occurred during the deposition of the Eocene formations.

The bottom of the hill consists of slightly inclined beds of white and greenish marls, more than three hundred feet in thickness, intersected by a dike of basalt, which may be studied in the ravine above the village of Merdogne. The dike here cuts through the

Fig. 130.



Hill of Gergovia.

* See Scrope's Central France, p. 7.

marly strata at a considerable angle, producing, in general, great alteration and confusion in them for some distance from the point of contact. Above the white and green marls, a series of beds of limestone and marl, containing fresh-water shells, are seen to alternate with volcanic tuff. In the lowest part of this division, beds of pure marl alternate with compact fissile tuff, resembling some of the subaqueous tuffs of Italy and Sicily called *peperinos*. Occasionally fragments of scoriæ are visible in this rock. Still higher is seen another group of some thickness, consisting exclusively of tuff, upon which lie other marly strata intermixed with volcanic matter.

There are many points in Auvergne where igneous rocks have been forced by subsequent injection through clays and marly limestones, in such a manner that the whole has become blended in one confused and brecciated mass, between which and the basalt there is sometimes no very distinct line of demarcation. In the cavities of such mixed rocks we often find calcedony, and crystals of mesotype, stilbite, and arragonite. To formations of this class may belong some of the breccias immediately adjoining the dike in the hill of Gergovia; but it cannot be contended that the volcanic sand and scoriæ interstratified with the marls and limestones in the upper part of that hill were introduced, like the dike, subsequently, by intrusion from below. They must have been thrown down like sediment from water, and can only have resulted from igneous action, which was going on contemporaneously with the deposition of the lacustrine strata.

The reader will bear in mind that this conclusion agrees well with the proofs, adverted to in the seventeenth chapter, of the abundance of silex, travertin,

and gypsum precipitated when the upper lacustrine strata were formed; for these rocks are such as the waters of mineral and thermal springs might generate.

The igneous products above mentioned, as associated with the lacustrine strata, form the lowest members of the great series of volcanic rocks of Auvergne, Cantal, and Velay, which repose for the most part on the granitic mountains (see Map above, p. 158.). There was evidently a long succession of eruptions, beginning with those of the Eocene period, and ending, so far as can yet be inferred from the evidence derived from fossil remains, with those of the Miocene epoch. The oldest part of the two principal volcanic masses of Mont Dor and the Plomb du Cantal may perhaps belong to the Eocene period,—the newer portion of the same mountains to the Miocene; just as Etna commenced its operations during the Newer Pliocene era, and has continued them down to the Recent epoch, and still retains its energy undiminished. There are some parts of the Mont Mezen, in Velay, which are perhaps of the same antiquity as the oldest parts of Mont Dor.

Besides these ancient rocks, of which the lavas are in a great measure trachytic, there are many minor cones in Central France, for the most part of posterior origin, which extend from Auvergne, in a direction north-west and south-east, through Velay, into the Vivarais, where they are seen in the basin of the Ardêche. This volcanic line does not pass by the Plomb du Cantal; it was formed, as nearly as can be conjectured in the present imperfect state of our knowledge, during the Miocene period; but there may probably be found, among these cones and their accompanying lavas, rocks of every intermediate age between

the oldest and newest volcanic formations of Central France.

I shall first give a brief description of the Mont Dor and the Plomb du Cantal, and then pass on to the train of newer cones, examining the evidence at present obtained respecting their relative ages, and the light which they throw on the successive formation of alluviums and on the excavation of valleys.

Mont Dor. — Mont Dor, the most conspicuous of the volcanic masses of Auvergne, rests immediately on the granitic rocks standing apart from the fresh-water strata.* This volcano rises suddenly to the height of several thousand feet above the surrounding platform, and retains the shape of a flattened and somewhat irregular cone, all the sides sloping more or less rapidly, until their inclination is gradually lost in the high plain around. This cone is composed of layers of scoriæ, pumice-stones, and their fine detritus, with interposed beds of trachyte and basalt, which descend often in uninterrupted currents, till they reach and spread themselves round the base of the mountain. † Conglomerates also, composed of angular and rounded fragments of igneous rocks, are observed to alternate with the above; and the various masses are seen to dip off from the central axis, and to lie parallel to the sloping flanks of the great cone, in the manner I have described when treating of Etna.

The summit of the mountain terminates in seven or eight rocky peaks, where no regular crater can now be traced, but where we may easily imagine one to have existed, which may have been shattered by earthquakes, and have suffered degradation by aqueous

* See the Map, p. 158.

† Scrope's Central France, p. 98.

agents. Originally, perhaps, like the highest crater of Etna, it may have formed an insignificant feature in the great pile, and may frequently have been destroyed and renovated.

We cannot at present determine the age of the great mass of Mont Dor, because no organic remains have yet been found in the tuffs, except impressions of the leaves of trees, of species not determined. Some of the lowest parts of the mountain are formed of white pumiceous tuffs, in which animal remains may perhaps be one day found. In the mean time, we may conclude that Mont Dor had no existence when the grits and conglomerates of the Limagne, which contain no volcanic materials, were formed; but some of the earliest eruptions were, perhaps, contemporary with those described in the commencement of this chapter. To the latest of these eruptions, on the other hand, I refer those trachytic breccias of Mont Perrier, which were shown in the sixteenth chapter (p. 147.) to alternate with Miocene alluviums.

Velay. — The observations of M. Bertrand de Doue have not yet established that any of the most ancient volcanos of Velay were in action during the Eocene period, although it is very probable that some of them may have been contemporaneous with the oldest of the Auvergne lavas. There are beds of gravel in Velay, as in Auvergne, covered by lava at different heights above the channels of the existing rivers. In the highest and most ancient of these alluviums the pebbles are exclusively of granitic rocks; but in the newer, which are found at lower levels, they contain an intermixture of volcanic substances. I have already shown, in the sixteenth chapter, that, in the volcanic ejections and alluviums covered by the lavas of Velay, the bones

of animals of Miocene species have been found, in which respect the phenomena accord perfectly with those of Auvergne.

Plomb du Cantal.—In regard to the age of the igneous rocks of the Cantal we are still less informed, and at present can merely affirm, that they overlie the Eocene lacustrine strata of that country. (See Map, Fig. 120.) They form a great dome-shaped mass, which has evidently been accumulated, like the cone of Etna, during a long series of eruptions. It is composed of trachytic, phonolitic, and basaltic lavas, tuffs, and conglomerates, or breccias, forming a mountain several thousand feet in height. Dikes also of phonolite, trachyte, and basalt are numerous, especially in the neighbourhood of the large cavity, probably once a crater, around which the loftiest summits of the Cantal are ranged circularly, few of them, except the Plomb du Cantal, rising far above the border or ridge of this supposed crater. A pyramidal hill, called the Puy Griou, occupies the middle of the cavity.* It is evident that the volcano of the Cantal broke out precisely on the site of the lacustrine deposit before described (Chapter xvii.), which had accumulated in a depression of a tract composed of micaceous schist. In the breccias, even to the very summit of the mountain, we find ejected masses of the fresh-water beds, and sometimes fragments of flint, containing Eocene shells. Valleys radiate in all directions from the central heights of the mountain, increasing in size as they recede from those heights. Those of the Cer and Jourdanne, which are more than twenty miles in length, are of great depth, and lay open the geological structure of the mountain.

* Mém. de la Soc. Géol. de France, tom. i. p. 175.

No alternation of lavas with undisturbed Eocene strata has been observed, nor any tuffs containing fresh-water shells, although some of these tuffs include fossil remains of terrestrial plants said to imply several distinct restorations of the vegetation of the mountain in the intervals between great periods of eruption. On the northern side of the Plomb du Cantal, at La Vissiere, near Murat, is a spot, pointed out on the Map (p. 158.), where fresh-water limestone and marl are seen covered by a thickness of about eight hundred feet of volcanic rock. Shifts are here seen in the strata of limestone and marl.*

Although it appears that the lavas of the Cantal are more recent than the fresh-water formation of that country, it does not follow that they may not belong to the Eocene period. The lake may possibly have been drained by the earthquakes which preceded or accompanied the first eruptions, but the Eocene animals and plants may have continued to exist for a long series of ages, while the cone went on increasing in dimensions.

Train of minor volcanos. — I shall next consider those minor volcanos, before alluded to, which stretch in a long range from Auvergne to the Vivarais, and which appear for the most part to be of newer origin than the mountains above described. These volcanos were faithfully described, so early as the year 1802, by M. de Montlosier. † They have been thrown up in a great number of isolated points, and much resemble those scattered over the Phlegræan fields and the flanks of Etna. They have given rise chiefly to currents of

* See Lyell and Murchison, Ann. des Sci. Nat., Oct. 1829.

† Théorie des Volc. d'Auvergne. — Clermont, An X.

basaltic lava, whereas those of Mont Dor and the Cantal are in great part trachytic. There are perhaps about 300 of these minor cones in Central France; but a part of them only occur in Auvergne, where some few are found at the bottom of valleys excavated through the more ancient lavas of Mont Dor, as the Puy de Tartaret, for example, whence issues a current of lava which, flowing into the bed of the river Couze, gave rise to the lake of Chambon. Here the more ancient columnar basalts of Auvergne are seen forming the upper portion of the precipices which bound the valley.

But the greater part of the minor cones of Auvergne are placed upon the granitic platform, where they form an irregular ridge, about eighteen miles in length and two in breadth. They are usually truncated at the summit, where the crater is often preserved entire, the lava having issued from the base of the hill. But frequently the crater is broken down on one side, where the lava has flowed out. The hills are composed of loose scoriæ, blocks of lava, lapilli, and puzzuolana, with fragments of trachyte and granite.

The lavas may be often traced from the crater to the nearest valley, where they usurp the channel of the river, which has often excavated a deep ravine through the basalt. We have thus an opportunity of contrasting the enormous degradation which the solid and massive rock has suffered by aqueous erosion, and the integrity of the cone of sand and ashes which has, in the mean time, remained uninjured on the neighbouring platform, where it was placed beyond the reach of the power of running water.

Puy de Côme. — The Puy de Côme and its lava current, near Clermont, may be mentioned as one of the

numerous illustrations of the phenomenon here alluded to.* This conical hill rises from the granitic platform, at an angle of about 40°, to the height of more than 900 feet. Its summit presents two distinct craters, one of them with a vertical depth of 250 feet. A stream of lava takes its rise at the western base of the hill, instead of issuing from either crater, and descends the granitic slope towards the present site of the town of Pont Gibaud. Thence it pours in a broad sheet down a steep declivity into the valley of the Sioule, filling the ancient river-channel for the distance of more than a mile. The Sioule, thus dispossessed of its bed, has worked out a fresh one between the lava and the granite of its western bank; and the excavation has disclosed, in one spot, a wall of columnar basalt about 50 feet high. †

The excavation of the ravine is still in progress, every winter some columns of basalt being undermined and carried down the channel of the river, and in the course of a few miles rolled to sand and pebbles. Meanwhile the cone of Côme remains stationary, its loose materials being protected by a dense vegetation, and the hill standing on a ridge not commanded by any higher ground whence floods of rain-water may descend.

Puy Rouge. — At another point, farther down the course of the Sioule, we find a second illustration of the same phenomenon in the Puy Rouge, a conical hill to the north of the village of Pranal. The cone is composed entirely of red and black scoriæ, tuff, and volcanic bombs. On its western side there is a worn-down

* Montlosier, Théorie des Volc. d'Auvergne, ch. ii.

† Scrope's Central France, p. 60., and plate.

crater, whence a powerful stream of lava has issued, and flowed into the valley of the Sioule. The river has since excavated a ravine through the lava and subjacent gneiss, to the depth of 400 feet.

On the upper part of the precipice forming the left side of this ravine, we see a great mass of black and red scoriaceous lava; below this a thin bed of gravel, evidently an ancient river-bed, now at an elevation of fifty feet above the channel of the Sioule. The gravel again rests upon gneiss, which has been eroded to the depth of 50 feet.* It is quite evident in this case, that, while the basalt was gradually undermined and carried away by the force of running water, the cone whence the lava issued escaped destruction, because it stood upon a platform of gneiss several hundred feet above the level of the valley in which the force of running water was exerted.

It is needless to multiply examples, or the Vivarais would supply many others equally striking. Among many I may instance the cone of Jaujac, and its lava current, which is a counterpart of that near Pranal last mentioned.†

Lavas and alluviums of different ages. — We have seen that on the flanks of Etna, since the commencement of the present century, several currents of lava have flowed at the bottom of the Val del Bove, at the foot of precipices formed of more ancient lavas and tuffs. So we find in Auvergne that some streams of melted matter have flowed in valleys, the sides of which consist partly of older lavas. These are often

* See Lyell and Murchison on the Excavation of Valleys, Edin. New Phil. Journ., July, 1829.

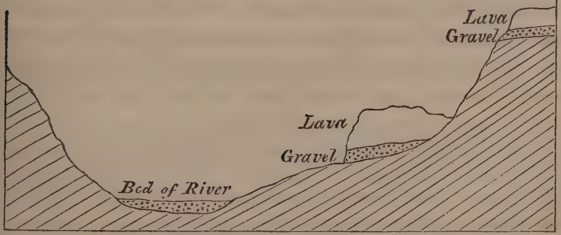
† Scrope's Central France, plate 14.

seen capping the hills in broad sheets, resting sometimes on granite, sometimes on fresh-water strata.

Many of the earlier lavas of Auvergne flowed out upon the platform of granite before all the existing valleys had been excavated; others again spread themselves in broad sheets over the horizontal lacustrine deposit, when these had been covered with gravel, probably soon after the drainage of the lakes. Great vicissitudes in the physical geography of the country must have taken place since the flowing of these ancient lavas; and it is evident that the changes were gradual and successive, caused probably by the united agency of running water and subterranean movements. We frequently observe one mass of lava capping a hill, and a second at a lower elevation, forming a terrace on the side of a valley; or sometimes occupying the bed of a river.

It is a most interesting fact, that in these cases beds of gravel almost invariably underlie the successive currents of lava, as in Catalonia before described (pp. 108. 111.). Occasionally, when the highest platform of lava is seven hundred or eight hundred feet above the lowest, we cannot fail to be struck with the

Fig. 131.



Lavas of Auvergne resting on alluviums of different ages.

wonderful alterations effected in the drainage of the country since the first current flowed; for the most elevated alluviums must originally have been accumulated on the lowest levels of the then existing surface. As some geologists have referred almost all the superficial gravels to one era, and have supposed them to be the result of one sudden catastrophe, the phenomena of Auvergne here alluded to are very important. The flows of volcanic matter have, in fact, preserved portions of the surface in the state in which they existed at successive periods; so that it is impossible to confound together the alluviums of different ages. The reader will see at once, by reference to the woodcut (Fig. 131.), that a considerable interval of time must have occurred between the formation of the uppermost bed of gravel and that next below it; during which interval the uppermost lava was poured out, and a valley excavated, at the bottom of which the second bed of gravel accumulated. In like manner the pouring out of a second current of lava, and a farther deepening of the valley, took place between the date of the second gravel and that of the modern alluvium which now fills the channel of the river.*

When rivers are dispossessed of their channels by lava, they usually flow between the mass of lava and one side of the original valley. They there eat out a passage, partly through the volcanic and partly through the older formation; but as the soft tertiary marls

* For localities in Central France where lavas or sheets of basalt repose on alluviums at different elevations above the present valleys, and for the inferences deducible from such facts, consult the works of MM. Le Grand d'Aussi, Montlosier, Ramond, Scrope, Bertrand de Doue, Croizet, Jobert, and Bouillet.

in Auvergne give way more readily than the basalt, it is usually at the expense of the marls that the enlarging and deepening of the new valley is effected; so that all the remaining lava is then left on one side, in the manner represented in the above woodcut.

Alluviums in ancient fissures.—It might have been expected, from the analogy of modern changes in volcanic countries, that we should find in Auvergne some signs of ancient fissures caused by earthquakes. Accordingly M. Fournet has observed in the course of excavations made for mining in the valley of the Sioule, near Clermont, some curious and decisive proofs of the former existence of open rents which must have communicated with the surface, and have been filled from above with alluvium, after the commencement and before the end of the period of volcanic eruptions. It appears that a metaliferous vein traversing gneiss (in other words, a mass or dike of matter, partly metallic and partly not, filling an old fissure in the gneiss) had been dislocated by later convulsions, so that a new rent was formed in it which reached the surface. Sand and gravel like that of a river-bed were then washed in, together with pieces of wood, which are now found fossil with the gravel, in a good state of preservation. The rounded pebbles are partly of granitic rocks, partly of basaltic and augitic lava, showing that the last filling up of the fissure occurred after some lavas had flowed over the adjacent country. But two of the most modern lava streams near Pont Gibaud, have passed over the top of the dike, and they must evidently have been poured out after it was filled with alluvium.*

* See Fournet, Traité de Geog., D'Aubuisson, tom. iii. p. 544.

Age of the more modern lavas.—The only organic remains found as yet in the ancient alluviums appear to belong to the Miocene period; but I have heard of none discovered in the gravel underlying the newest lavas,—those which either occupy the channels of the existing rivers, or are very slightly elevated above them. I think it not improbable that even these may be of Miocene date, although the conjecture will appear extremely rash to some who are aware that the cones and craters whence the lavas issue are often as fresh in their aspect as the majority of the cones of the forest zone of Etna.

The brim of the crater of the Puy de Pariou, near Clermont, is so sharp, and has been so little blunted by time, that it scarcely affords room to stand upon. This and other cones in an equally remarkable state of integrity have stood, I conceive, uninjured, not *in spite* of their loose porous nature, as might at first be naturally supposed, but in consequence of it. No rills can collect where all the rain is instantly absorbed by the sand and scoriæ, as was shown to be the case on Etna (see Vol. III. p. 455.); and nothing but a waterspout breaking directly upon the Puy de Pariou could carry away a portion of the hill, so long as it is not rent or engulphed by earthquakes.

Attempt to divide volcanos into ante-diluvian and post-diluvian.—The opinions above expressed are entirely at variance with the doctrines of those writers who have endeavoured to arrange all the volcanic cones of Europe under two divisions, those of ante-diluvian and those of post-diluvian origin. To the ante-diluvian class they attribute such hills of sand and scoriæ as exhibit on their surface evident signs of aqueous denudation; to the post-diluvian, such as betray no marks

of having been exposed to such aqueous action. According to this classification, almost all the minor cones of Central France must be called post-diluvian; although, if we receive this term in its ordinary acceptation, as denoting posteriority of date to the Noachian deluge, we are forced to suppose that all the volcanic eruptions occurred within a period of little more than twenty centuries, or between the era of the flood, which happened about four thousand years ago, and the earliest historical records handed down to us respecting the former state of Central France. Dr. Daubeny has justly observed, that had any of these French volcanos been in a state of activity in the age of Julius Cæsar, that general, who encamped upon the plains of Auvergne, and laid siege to its principal city (Gergovia, near Clermont), could hardly have failed to notice them. Had there been even any record of their existence in the time of Pliny or Sidonius Apollinaris, the one would scarcely have omitted to make mention of it in his Natural History, nor the other to introduce some allusion to it among the descriptions of this his native province. This poet's residence was on the borders of the Lake Aidat, which owed its very existence to the damming up of a river by one of the most modern lava-currents.*

The ruins of several Roman bridges, and of the Roman baths at Royat, confirm the conclusion that no sensible alteration has taken place in the physical geography of the district, not even in the chasms excavated through the newest lavas since ages historically remote. We have no data at present for

* Daubeny on Volcanos, p. 14.

presuming that any one of the Auvergne cones has been produced within the last four or five thousand years; and the same may be said of those of Velay; and, until the bones of men or articles of human workmanship are found buried under some of their lavas, instead of the remains of extinct animals, which alone have hitherto been met with, we are justified in regarding it as probable that the latest of the volcanic eruptions may have occurred during the Miocene period.

Supposed effects of the Flood.

They who have used the terms ante-diluvian and post-diluvian, in the manner above adverted to, proceed on the assumption that there are clear and unequivocal marks of the passage of a general flood over all parts of the surface of the globe. It had long been a question among the learned, even before the commencement of geological researches, whether the deluge of the Scriptures was universal in reference to the whole surface of the globe, or only so with respect to that portion of it which was then inhabited by man. If the latter interpretation be admissible, it will appear from other parts of this work that there are two classes of phenomena in the configuration of the earth's surface, which might enable us to account for such an event. First, extensive lakes elevated above the level of the ocean; secondly, large tracts of dry land depressed below that level. When there is an immense lake, having its surface, like Lake Superior, raised six hundred feet above the level of the sea, the water may be suddenly let loose by the rending or sinking down of the barrier during earthquakes, and hereby a region

as extensive as the valley of the Mississippi, inhabited by a population of several millions, might be deluged.* On the other hand, if there be any country placed beneath the mean level of the ocean, as some have supposed to be the case with part of Asia †, the depressed region must be entirely laid under water, if the tract which separates it from the ocean be fissured or depressed to a certain depth. Humboldt inferred, from the observations of Parrot, that a great cavity existed in Western Asia, eighteen thousand square leagues in area, and occupied by a considerable population.‡ The lowest parts, surrounding the Caspian Sea, were said to be about 350 feet below the level of the Euxine,—here, therefore, the diluvial waters might overflow the summits of hills rising 350 feet above the level of the plain; and if depressions still more profound existed in any former time in Asia, the tops of still loftier mountains may have been covered by a flood.§

* Vol. I. p. 130. † Vol. III. p. 148.

‡ Fragmens Asiatiques, Paris, 1831.

§ While this sheet was passing through the press I received a copy of the "Reise zum Ararat," just published by Professor Parrot, of Dorpat; and was surprised to find that he doubts, nay appears wholly to have disproved the fact so long believed on his authority, of a difference of level between the Black Sea and the Caspian. The opinion was originally adopted on the authority of barometrical measurements, made by him and M. Engelhardt in 1811. M. Parrot, however, on revisiting the country in 1829 and 1830, was led to suspect the correctness of his former observations on several grounds, one of which only I shall now quote. Russian engineers had ascertained by accurate measurements, that the Don, at the place called Katschalinsk, where it is only sixty wersts distant from the Wolga, is 130 Paris feet *higher* than the latter river, and that the Don flows with much greater rapidity to the Black Sea than the Wolga does to the Caspian; con-

But the great majority of the older commentators have held the deluge, according to the brief account of the event given by Moses, to have consisted of a rise of waters over *the whole earth*, by which the summits of the loftiest mountains on the globe were submerged. Many have indulged in speculations concerning the instruments employed to bring about the grand cataclysm; and there has been a great division of opinion as to the effects which it might be expected to have produced on the surface of the earth. According to one school, of which De Luc in former times, and more recently Dr. Buckland, have been zealous supporters, the passage of the flood worked a considerable alteration in the external configuration of our continents. By Dr. Buckland the deluge has been represented as a violent and transient rush of waters which tore up the soil to a great depth, excavated valleys, gave rise to immense beds of shingle, carried fragments of rock and gravel from one point to another; and, during its advance and retreat, strewed the

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sequently, if there be a difference of level of the two seas, it must be considerably less than 130 feet. Parrot accordingly, determined to ascertain the truth, made a series of levellings from the mouth of the Wolga to Zarytzin, 400 wersts up its course, and from the mouth of the Don to the like distance. The result was that he made the mouth of the Don between three and four feet *lower* than that of the Wolga! Baron Humboldt, who with other geographers had given full credit to the former statement of Parrot, refused to admit the validity of these new results, unless the professor was prepared to show that his former observations were less worthy of confidence. In reply to this, Parrot, in an Appendix, admits that their barometrical instruments used in 1811 were not quite perfect, that some errors had crept into his calculations, that he was suffering from ill health, &c. &c.

valleys, and even the tops of many hills, with alluvium.*

But I agree with Dr. Fleming, that in the narrative of Moses there are no terms employed that indicate the impetuous rushing of the waters, either as they rose or when they retired, upon the restraining of the rain and the passing of a wind over the earth.† On the contrary, the olive-branch, brought back by the dove, seems as clear an indication to us that the vegetation was not destroyed, as it was then to Noah that the dry land was about to appear.

I have been led with great reluctance into this digression, in the hope of relieving the minds of some readers from groundless apprehension respecting the bearing of many of the views advocated in this work. They have been in the habit of regarding the diluvial theory above controverted as alone capable of affording an explanation of geological phenomena in accordance with Scripture, and they may have felt disapprobation at an attempt to prove, in a former chapter, that the minor volcanos on the flanks of Etna may, some of them, be more than 10,000 years old.‡ How, they would immediately ask, could they have escaped the denuding force of a diluvial rush of waters? The same objection may have presented itself when I quoted, with respect, the opinion of a distinguished botanist, that some living specimens of the Baobab tree of

* Buckland, Reliquiæ Diluvianæ.

† See a Memoir by the Rev. John Fleming, D. D., on the Geological Deluge, Edin. Phil. Journ., vol. xiv. p. 205. His opinions were reviewed by the author of the present volume in Oct. 1827, in an article in the Quarterly Review, No. lxxii. p. 481.

‡ Vol. III. p. 453.

Africa, or the Taxodium of Mexico, may be 5000 years old.* The reader may also have been astonished at the high antiquity assigned to the greater part of the European alluviums, and the many different ages to which I have referred them†, as he may have been taught to consider the whole as the result of one *recent* and *simultaneous* inundation.

Professor Sedgwick is inclined to adopt the hypothesis of M. Elie de Beaumont, that the sudden elevation of mountain-chains "has been followed again and again by mighty waves desolating whole regions of the earth‡;" a phenomenon which he thinks has "taken away all anterior incredibility from the fact of a recent deluge."§

But I cannot admit that there are sufficient geological data for inferring such instantaneous upheavings of submerged land as might be capable of causing a flood over a whole continent at once. I may also observe, that the reasoning above alluded to seems to proceed entirely on the assumption that the flood of Noah was brought about by *natural* causes, just as some writers have contended that a volcanic eruption was the instrument employed to destroy Sodom and Gomorrah. If we believe the flood to have been a temporary suspension of the ordinary laws of the natural world, requiring a miraculous intervention of Divine power, then it is evident that the credibility of such an event cannot be enhanced by any series of inundations, however analogous, of which the geologist may imagine that he has discovered the proofs.

* See Vol. III. p. 451.

† Vol. IV. p. 58. ‡ Vol. III. p. 454.

§ Sedgwick, Anniv. Address to the Geol. Soc., Feb. 18th, 1831.

For my own part, I have always considered the flood, when its universality in the strictest sense of the term is insisted upon, as a preternatural event far beyond the reach of philosophical inquiry, whether as to the causes employed to produce it, or the effects most likely to result from it. At the same time, it is clear that they who are desirous of pointing out the coincidence of geological phenomena with the occurrence of such a general catastrophe, must neglect no one of the circumstances enumerated in the Mosaic history, least of all so remarkable a fact as that the olive remained standing while the waters were abating.

Recapitulation. — I shall now briefly recapitulate some of the principal conclusions to which we have been led by an examination of the volcanic districts of Central France.

1st. Some of the volcanic eruptions of Auvergne took place during the Eocene period; others at an era long subsequent, probably during the Miocene period.

2ndly. There are no proofs as yet discovered that the most recent of the volcanos of Auvergne and Velay are subsequent to the Miocene period, the integrity of many cones and craters not opposing any sound objection to the opinion that they may be of very great antiquity.

3rdly. There are alluviums in Auvergne of very different ages, some of them belonging to the Miocene period. Many of these have been covered by lava-currents which have been poured out in succession while the excavation of valleys was in progress.

4thly. There are a multitude of cones in Auvergne, Velay, and the Vivarais, which have never been sub-

jected to the action of a violent rush of waters capable of modifying considerably the surface of the earth.

5thly. If, therefore, the Mosaic deluge be represented as universal, and as having exercised a violent denuding force, all these cones, several hundred in number, must be post-diluvian.

6thly. But since the beginning of the historical era, or the invasion of Gaul by Julius Cæsar, the volcanic action in Auvergne has been dormant; and there is nothing to countenance the idea that, between the date usually assigned to the Mosaic deluge and the earliest traditional and historical records of Central France (a period of little more than twenty centuries), all or any one of the more entire cones of loose scoriæ were thrown up.

Lastly. It is the opinion of some writers, that the earth's surface underwent no great modification at the era of the Mosaic deluge, and that the strictest interpretation of the Scriptural narrative does not warrant us in expecting to find any geological monuments of the catastrophe; an opinion which would be consistent with the preservation of these volcanic cones, however high their antiquity.

CHAPTER XX.

EOCENE FORMATIONS — *continued.*

Basin of the Cotentin, or Valognes — Rennes — Basin of the Netherlands — Aix, in Provence — Fossil insects — Vicentine — Tertiary strata of England — Basins of London and Hampshire — Different groups — Plastic clay and sand — London clay (p. 227.)— Bagshot sand — Fresh-water strata of the Isle of Wight— Palæotherium and other fossils of Binstead — English Eocene strata conformable to chalk — Outliers on the elevated parts of the chalk (p. 231.).

In addition to the Eocene formations treated of in the last three chapters, there are others in the north of Europe, the geographical position of which is delineated on the annexed map.*

Basin of the Cotentin, or Valognes. — The strata in the environs of Valognes, in the department of La Manche, consist chiefly of a coarse limestone resembling the calcaire grossier of Paris, of which M. Desnoyers has given an elaborate description. It is occasionally covered with a compact fresh-water limestone alternating with fresh-water marls. In these Eocene strata more than 300 species of fossil shells have been discovered, almost all identical with species of the

* This map is copied from one given by M. Desnoyers, Mém. de la Soc. d'Hist. Nat. de Paris, 1825, pl. 9.; compiled partly from that author's observations, and partly from Mr. Webster's map, Geol. Trans., 1st series, vol. ii. plate 10.

Paris basin. Superimposed upon the Eocene strata of this basin is a newer marine deposit, extending over a

MAP OF THE PRINCIPAL TERTIARY BASINS OF THE EOCENE PERIOD.

Fig. 132.

Primary rocks and strata older than the carboniferous series. Eocene formations.

N. B. The space left blank is occupied by secondary formations, from the old red sandstone to the chalk inclusive.

limited area, the fossils of which agree with those of the faluns of the Loire.* Here, therefore, the geologist has an opportunity of observing the superposition of the Miocene deposits upon those of the age of the Paris basin.

Rennes. — Several small patches, also, of marine strata, have been found by M. Desnoyers, in the neighbourhood of Rennes, which are characterized by Eocene fossils and repose on ancient rocks, as will be seen in the map.

* Desnoyers, Mém. de la Soc. d'Hist. Nat. de Paris, 1825.

Basin of Belgium, or the Netherlands.—The greater part of the tertiary formations of the Low Countries consist of clay and sand, much resembling those of the basin of London, afterwards to be described; and the fossil shells are of the same species.

Aix in Provence.—The tertiary strata of Aix and Fuveau, in Provence, are of great thickness and extent, the lower members being remarkable for containing coal grit and beds of compact limestone, such as in England are found only in ancient secondary groups. Yet these strata are for the most part of fresh-water origin, and contain several species of Eocene shells, together with many which are peculiar to this basin. It will require a fuller comparison than has yet been made of the fossil remains of Aix and Fuveau, before we can determine with accuracy the relative age of this formation. Some of the plants seem to agree with those of the Paris basin, while many of the insects have been supposed identical with species now living.* These insects have been almost exclusively procured from a thin bed of grey calcareous marl, which passes into an argillaceous limestone found in the quarries of gypsum near Aix. The rock in which they are imbedded is so thinly laminated, that there are sometimes more than seventy layers in the thickness of an inch. The insects are for the most part in an extraordinary state of preservation, and an impression of their form is seen both on the upper and under laminæ, as in the case of the Monte Bolca fishes. M. Marcel de Serres enumerates sixty-two genera, belonging chiefly to the orders Diptera, Hemiptera, and Coleoptera. On re-

* M. Marcel de Serres, Géog. des Ter. Tertiaires du Midi de la France.

viewing a collection brought from Aix, Mr. Curtis observes that they are all of European forms, and most of them referrible to existing genera.* With the single exception of an Hydrobius, none of the species are aquatic. The antennæ, tarsi, and trophi are generally very obscure, or distorted; yet in a few the claws are visible, and the sculpture, and even some degree of local colouring, are preserved. The nerves of the wings, in almost all the Diptera, are perfectly distinct, and even the pubescence on the head of one of them. Several of the beetles have the wings extended beyond the elytra, as if they had made an effort to escape by flying, or had fallen into the water while on the wing.†

Vicentine.—On the Southern flank of the Alps to the north of Vicenza, in Italy, a limestone occurs containing shells of Eocene species, and in the basaltic tuffs associated with this limestone (as at Ronca and other places) shells are found which are also identical with species of the Paris basin.‡

Basins of London and Hampshire.

The reader will see in the small map above given (Fig. 132. p. 222.), the position of the two districts usually called the basins of London and Hampshire, to which the Eocene formations of England are confined. These tracts are bounded by rising grounds composed of chalk, except where the sea intervenes. That the chalk passes beneath the tertiary strata, we can not only infer from geological data, but can prove by numerous artificial sections at points where wells

* Murchison and Lyell. Ed. New Phil. Journ., Oct. 1829.

† Curtis, ibid., where figures of some of the insects are given.

‡ See list of species collected by M. Boué, and named by M. Deshayes, Bull. de la Soc. Géol. de France, tom. iii. p. 91.

have been sunk, or borings made through the overlying beds. The Eocene deposits are chiefly marine, and have generally been divided into three groups: 1st, the Plastic clay and sand, which is the lowest group; 2dly, the London clay; and, 3dly, the Bagshot sand. Of all these the mineral composition is very simple; for they consist almost entirely of clay, sand, and shingle, the great mass of clay being in the middle, and the upper and lower members of the series being more arenaceous.

Plastic clay and sand.—The lowest formation, which sometimes attains a thickness of from four hundred to five hundred feet, consists principally of an indefinite number of beds of sand, shingle, clay, and loam, irregularly alternating, some of the clay being used in potteries, in reference to which the name of Plastic clay has been given to the whole formation. The beds of shingle are composed of perfectly rolled chalk flints, with here and there small pebbles of quartz. Heaps of these materials appear sometimes to have remained for a long time covered by a tranquil sea. Dr. Buckland mentions that he observed a large pebble in part of this formation at Bromley, to which five full-grown oyster-shells were affixed, in such a manner as to show that they had commenced their first growth upon it, and remained attached through life.*

In some of the associated clays and sand, perfect marine shells are met with, which are of the same species as those of the London clay. The line of separation, indeed, between this superincumbent blue clay and the Plastic clay and sand is quite arbitrary, as any geologist may be convinced who examines the

* Geol. Trans., First Series, vol. iv. p. 300.

celebrated section in Alum Bay, in the Isle of Wight, where a distinct alternation of the two groups is observable, each marked with their most characteristic peculiarities.* In the midst of the sands of the lower series a mass of clay occurs two hundred feet thick, containing septaria, and replete with the usual fossils of the neighbourhood of London.†

The *arenaceous* beds are chiefly laid open on the confines of the basins of London and Hampshire, in following which we discover at many places great beds of perfectly rounded flints. Of this description, on the southern borders of the basin of London, are the hills of Comb Hurst and the Addington hills, which form a ridge stretching from Blackheath to Croydon. Here they have much the appearance of banks of sand and shingle formed near the shores of a tertiary sea; but whether they were really of littoral origin cannot be determined, for want of a sufficient number of sections, which might enable us to compare the tertiary strata at the edges with those in the central parts of each basin.

We have ample opportunities in the basin of Paris of examining steep cliffs of hard rock, which bound many of the valleys, and innumerable excavations have been made for building-stone, limestone, and gypsum; but when we attempt to obtain a connected view of any considerable part of the tertiary series in the basin of London, we are almost entirely limited to a single line of coast-section; for in the interior

* See Mr. Webster's Memoir, Geol. Trans., vol. ii., First Series, and his Letters in Sir H. Englefield's Isle of Wight.

† See Mr. Webster's Sections, plate 11. Geol. Trans., vol. ii., First Series.

the regular beds are much concealed by an alluvial covering of flint gravel spread alike over the summits and gentle slopes of the hills, and over the bottoms of the valleys.

Organic remains are extremely scarce in the Plastic clay; but when any shells occur they are of Eocene species. Vegetable impressions and fossil wood are sometimes met with, and even beds of lignite; but none of the *species* of plants have, I believe, as yet been ascertained.

London clay. — This formation consists of a bluish or blackish clay, sometimes passing into a calcareous marl, rarely into a solid rock. Its thickness is very great, sometimes exceeding five hundred feet. * It contains many layers of ovate or flattish masses of argillaceous limestone, which, in their interior, are generally traversed in various directions by cracks, partially or wholly filled by calcareous spar. These masses, called septaria, are sometimes continued through a thickness of two hundred feet. †

A great number of the marine shells of this clay have been identified with those of the Paris basin; and it is quite evident that the strata of these two basins belong to the same epoch.

No remains of terrestrial mammalia have as yet been found in this clay; but the occurrence of bones and skeletons of crocodiles and turtles prove, as Mr. Conybeare justly remarks, the existence of neighbouring dry land. The shores, at least, of some islands were accessible, whither these creatures may have resorted to lay their eggs. In like manner, we may infer the con-

* Con. and Phil. Outlines of Geol., p. 33.

† Outlines of Geol., p. 27.

tiguity of land from the immense number of ligneous seed-vessels of plants, some of them resembling the cocoa-nut, and other spices of tropical regions, which have been found fossil in great profusion in the Isle of Sheppey. Such is the abundance of these fruits, that they have been supposed to belong to several hundred distinct species of plants.

Bagshot sand. — The third and uppermost group, usually termed the Bagshot sand, rests conformably upon the London clay, and consists of siliceous sand and sandstone devoid of organic remains, with some thin deposits of marl associated. From these *marls* a few marine shells have been obtained which are in an imperfect state, but appear to belong to Eocene species common to the Paris basin.*

Fresh-water strata of the Hampshire basin. — In the northern part of the Isle of Wight, and part of the opposite coast of Hampshire, fresh-water strata occur resting on the London clay. They are composed chiefly of calcareous and argillaceous marls, interstratified with some thick beds of siliceous sand, and a few layers of limestone sometimes slightly siliceous. The marls are often green, and bear a considerable resemblance to the green marls of Auvergne and the Paris basin. The shells and gyrogonites also agree specifically with some of those most common in the French deposits. Mr. Webster, who first described the fresh-water formation of Hampshire, divided it into an upper and lower series, separated by intervening beds of marine origin. There are undoubtedly certain intercalated strata, both in the Isle of Wight and coast of Hampshire, marked by a slight inter-

* Warburton, Geol. Trans., vol. i., Second Series.

mixture of marine and fresh-water shells, sufficient to imply a temporary return of the sea, before and after which the waters of a lake, or rather, perhaps, some large river, prevailed. * The united thickness of the fresh-water and intercalated upper marine beds, exposed in a vertical precipice in Headen Hill, in the Isle of Wight, is about four hundred feet, the marine series appearing about half way up in the cliff.

Eocene mammiferous remains.—Very perfect remains of tortoises and the teeth of crocodiles have been procured from the fresh-water strata; but a still more interesting discovery has recently been made. The bones of mammalia, corresponding to those of the celebrated gypsum of Paris, have been disinterred at Binstead, near Ryde, in the Isle of Wight. In the ancient quarries near this town a limestone, belonging to the lower fresh-water formation, is worked for building. Solid beds alternate with marls, wherein a tooth of an Anoplotherium, and two teeth of the genus Palæotherium, were found. These remains were accompanied not only by several other fragments of the bones of Pachydermata (chiefly in a rolled and injured state), but also by the jaw of a new species of Ruminantia, apparently closely allied to the genus Moschus. † Mr. T. Allan of Edinburgh had several years before found the tooth of an Anoplotherium at the same spot.

These newer strata of the Isle of Wight bear a certain degree of resemblance to some of the green

* See Memoirs of Mr. Webster, Geol. Trans., vol. ii., First Series; vol. i. part i., Second Series; and Englefield's Isle of Wight. — Professor Sedgwick, Ann. of Phil., 1822; and Lyell, Geol. Trans. vol. ii., Second Series.

† Pratt, Proceedings of Geol. Soc., No. 18. p. 239.

marls and limestones in the Paris basin; yet, as a whole, no formations can be more dissimilar in mineral character than the Eocene deposits of England and Paris. In our own island the tertiary strata are more exclusively marine; and it might be said that the Parisian series differs chiefly from that of London in the very points in which it agrees with the formations of Auvergne, Cantal, and Velay. The tertiary formations of England are, in fact, almost exclusively of mechanical origin, and their composition bespeaks the absence of those mineral and thermal waters to which I have attributed the origin of the compact and siliceous limestones, the gypsum, and beds of pure flint, common to the Paris basin and Central France.

English tertiary strata conformable to the chalk.— The British Eocene strata are nearly conformable to the chalk on which they rest, being horizontal where the strata of the chalk are horizontal, and vertical where they are vertical. On the other hand, there are evident signs that the surface of the chalk had, in many places, been furrowed by the action of the waves and currents, before the Plastic clay and its sands were superimposed. In the quarries near Rochester and Gravesend, for instance, fine examples are seen of deep indentations on the surface of the chalk, into which sand, together with rolled and angular pieces of chalk-flint, have been swept.* But these appearances may be referred to the action of water when the chalk began to emerge during the Eocene period, and they by no means warrant the conclusion that the chalk had undergone any con-

* Con. and Phil., Outlines of Geol., p. 62.

siderable change of position before the tertiary strata were superimposed.

In this respect there is a marked difference between the reciprocal relations of our secondary and tertiary rocks and those which exist between the same groups throughout the greater part of the Continent, especially in the neighbourhood of mountain-chains. Near the base, for example, of the Alps, Apennines, and Pyrenees, we find the newer formations reposing unconformably upon the truncated edges of the older beds; and it is clear that, in many cases, the older strata had been subjected to a complicated series of movements before the more modern set was formed. The newer beds rise only to a certain height on the flanks of the mountains which usually tower above them, and are recognized at once by the geologist as having been already converted into land when the tertiary deposits were still forming in the sea. The ancient borders also of that sea can often be defined with certainty, and the outline of some of its bays and sea-cliffs traced.

In England, although undoubtedly the greater portion of the tertiary strata is confined to certain spaces, we find outlying patches here and there at great distances beyond the general limits, and at great heights upon the chalk which separates the basins of London and Hampshire.* I have seen masses of clay extending in this manner to near the edge of the western escarpment of the chalk of Wiltshire, and Mr. Mantell has pointed out the same to me in the South Downs. Near the escarpment at Lewes, for example, there is a fissure in the chalk filled with sand, and with a fer-

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 125.

ruginous breccia, such as usually marks the lower members of the Plastic clay formation. From the occurrence of these tertiary outliers Dr. Buckland inferred, "that the basins of London and Hants were originally united together in one continuous deposit across the now intervening chalk of Salisbury Plain in Wilts, and the plains of Andover and Basingstoke in Hants; and that the greater integrity in which the tertiary strata are preserved within the basins has resulted from the protection which their comparatively low position has afforded them from the ravages of diluvial denudation."*

I agree so far with this conclusion as to believe that the basins of London and Hampshire were not separated until part of the tertiary strata were deposited; but I do not think it probable that the tertiary beds ever extended continuously over those spaces where the outliers above mentioned occur, nor that the comparative thinness of those deposits in the higher chalk countries should be attributed chiefly to the greater degree of denudation which they have there suffered.

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 126.

GEOLOGICAL MAP of the South East of ENGLAND, Exhibiting the Denudation OF THE WEALD.
LONDON
MOUTH of the THAMES
BASIN OF LONDON
BASIN OF HANTS
Forest Range
Tilgate Forest
G.t Marlow
Beaconsfield
Henley
R. Thames
Maidenhead
Windsor
Reading
R. Kennet
Oakingham
Bagshot
Staines
Brentford
Richmond
Kingston
R. Mole
R. Wey
Romford
Rochford
Woolwich
Greenwich
Purfleet
Gravesend
R. Medway
I. of Sheppey
Margate
N. Foreland
I. of Thanet
Ramsgate
Bromley
Croydon
Farnborough
Chatham
Sittingbourne
Feversham
Canterbury
Deal
Barham
S. Foreland
Elham
Dover
Folkestone
Hythe
R. Stour
Leatherhead
Merstham
Darent R.
Maidstone
Lenham
Odiham
Guildford
Farnham
Dorking
Tunbridge
Alton
Godalming
Haslemere
Crawley
E. Grinstead
Tunbridge Wells
Cranbrook
Tenterden
Horsham
Cuckfield
Petersfield
Midhurst
Petworth
R. Rother
Romney Marsh
New Romney
Denge Ness
Greenhurst
Adur R.
Ouse R.
Barcombe
Uckfield
Battle
Winchelsea
Hastings
Steyning
Bramber
Lewes
Shoreham
Brighton
Cuckmere R.
PEVENSEY B.
Beachy Hd.
Newhaven
Chichester
Havant
Portsmouth
R. Arun
Worthing
Selsea Bill
I. of Wight
Scale of Miles
0 5 10 15 20 25
1 Chalk and Firestone
2 Gault
3 Lower Green Sand
4 Weald Clay
5 Hastings Sand
Tertiary Strata

CHAPTER XXI.

ORIGIN OF THE ENGLISH EOCENE FORMATIONS AND DENUDATION OF THE WEALD.

Manner in which the English tertiary strata may have originated — Denudation of secondary strata during their deposition — Valley of the Weald — Secondary rocks of the Weald divisible into five groups — North and South Downs — Section across the valley of the Weald — Anticlinal axis — Chalk escarpments once sea-cliffs (p. 239.) — Rise and denudation of the strata gradual — Parallel ridges and valleys formed by harder and softer beds — No ruins of the chalk on the central district of the Weald (p. 247.) — Double system of valleys, the longitudinal and the transverse (p. 250.)

Preliminary views.—In explanation of the phenomena described in the last chapter, I shall now endeavour to lay before the reader a view of the series of events which may have produced the leading geological and geographical features of the south-east of England. I conceive that the chalk, together with many subjacent rocks, may have remained undisturbed and in horizontal stratification until after the commencement of the Eocene period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were soon after exposed to denudation. The waste of all these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary

sands and clays; while the chalk was the source of flinty shingle, and of the calcareous matter which we find intermixed with the Eocene clays. The tracts now separating the basins of London and Hampshire were those first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising.

Denudation of the Valley of the Weald.—In order to understand this theory, it will be necessary that the reader should be acquainted with the phenomena of denudation exhibited by the chalk and some of the older secondary rocks in parts of England, most nearly contiguous to the basins of London and Hampshire. It will be sufficient to consider one of the denuded districts, as the appearances observable in others are strictly analogous; I shall, therefore, direct attention to what may be called *the Valley of the Weald*, or the region intervening between the North and South Downs.

Map.—The district alluded to is delineated in the coloured map, given in Plate XV., which has been chiefly taken from Mr. Greenough's Map of England; and it will be there seen that the southern portion of the basin of London, and the north-eastern limits of that of Hampshire, are separated by a tract of secondary rocks, between forty and fifty miles in breadth, comprising within it the whole of Sussex, and parts of the counties of Kent, Surrey, and Hampshire.

There can be no doubt that the tertiary deposits of the Hampshire basin formerly extended much farther along our southern coast towards Beachey Head, for

patches are still found near Newhaven, and at other points, as will be seen by the map. These are now wasting away, and will in time disappear, as the sea is constantly encroaching and undermining the subjacent chalk.

The secondary rocks, depicted on the map, may be divided into five groups: —

1. *Chalk and Upper green-sand.* — This group is the uppermost of the series; it includes the white chalk with and without flints, and an inferior deposit, called, provincially, "Firestone," and by English geologists, the "Upper green-sand." It sometimes consists of loose siliceous sand, containing grains of silicate of iron, but often of firm beds of sandstone and chert.
2. Blue clay or calcareous marl, called, provincially, *Gault.*
3. *Lower green-sand*, a very complex group, consisting of grey, yellowish, and greenish sands; ferruginous sand and sandstone; clay, chert, and siliceous limestone.
4. *Weald clay*, composed for the most part of clay without intermixture of calcareous matter, but sometimes including thin beds of sand and shelly limestone.
5. *Hastings sands*, composed chiefly of sand, sandstone, clay, and calcareous grit, passing into limestone.*

The first three formations above enumerated are of marine origin; the last two, Nos. 4. and 5., contain

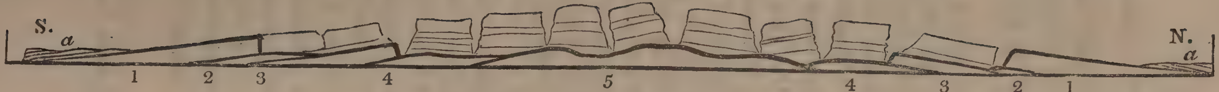
* For an account of these strata in the south-east of England, see Mantell's Geology of Sussex, and Dr. Fitton's Geology of Hastings, where the memoirs of all the writers on this part of England are referred to.

almost exclusively the remains of fresh-water and amphibious animals. But it is not my intention to enlarge, at present, upon the organic remains of these formations, as the rocks are merely adverted to, in order that I may describe the changes of position which they have undergone, and the denudation to which they have been exposed since the commencement of the Eocene period,—mutations which, if the theory about to be explained be well founded, belong strictly to the history of *tertiary* phenomena.

By a glance at the map, the reader may trace at once the superficial area occupied by each of the five formations above mentioned. On the west will be seen a large expanse of chalk, from which two branches are sent off; one through the hills of Surrey and Kent to Dover, forming the ridge called the North Downs; and the other through Sussex to the sea at Beachy Head, constituting the South Downs. The space comprised between the North and South Downs, or, "the Valley of the Weald," consists of the formations Nos. 2, 3, 4, 5, of the above table. It will be observed that the chalk terminates abruptly, and with a well-defined line towards the country occupied by those older strata. Within that line is a narrow band, coloured blue, formed by the gault; and within this again, is the Lower green-sand, next the Weald clay; and then, in the centre of the district, a ridge formed by the Hastings sands.

Section of the Valley of the Weald.—It has been ascertained, by careful investigation, that if a line be drawn from any part of the North to the South Downs, which shall pass through the central group (No. 5.), the beds will be found arranged in the order described in the annexed section (Fig. 133.).

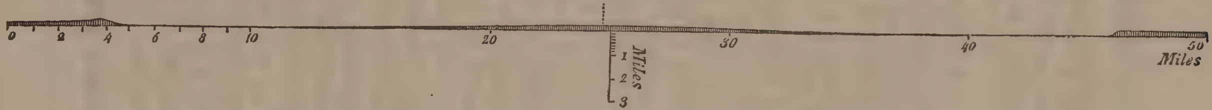
Fig. 133.



Section from the London to the Hampshire basin across the valley of the Weald.

a. Tertiary strata. 1. Chalk and firestone. 2. Gault. 3. Lower green-sand. 4. Weald clay. 5. Hastings sands.

Fig. 134.



Section of the country from the confines of the basin of London to that of Hants, with the principal heights above the level of the sea on a true scale.†

* Lieutenant H. Murphy, R. E., informs me that Botley Hill, near Godstone, in Surrey, was found by trigonometrical measurement to be 880 feet above the level of the sea; and Wrotham Hill, near Maidstone, which appears to be next in height of the North Downs, 795 feet.

† My friend Mr. Mantell, of Lewes, has kindly drawn up this scale at my request.

The reader is referred at present to the dark lines of the section, as the fainter lines represent portions of rock supposed to have been carried away by denudation.

At each end of the diagram the tertiary strata, *a*, are exhibited reposing on the chalk. In the centre are seen the Hastings sands (No. 5.), forming an anticlinal axis, on each side of which the other formations are arranged with an opposite dip. It has been necessary, however, in order to give a clear view of the different formations, to exaggerate the proportional height of each in comparison to its horizontal extent; and a true scale is therefore subjoined in another diagram (Fig. 134.), in order to correct the erroneous impression which might otherwise be made on the reader's mind. In this section the distance between the North and South Downs is represented to exceed forty miles; for the valley of the Weald is here intersected in its longest diameter, in the direction of a line between Lewes and Maidstone.

In attempting to account for the manner in which the five secondary groups above mentioned may have been brought into their present position, the following hypothesis has been very generally adopted:—Suppose the five formations to lie in horizontal stratification at the bottom of the sea; then let a movement from below press them upwards into the form of a flattened dome, and let the crown of this dome be afterwards cut off, so that the incision should penetrate to the lowest of the five groups. The different beds would then be exposed on the surface, in the manner exhibited in the map, Pl. XV.*

* See illustrations of this theory by Dr. Fitton, Geol. Sketch of Hastings.

It will appear, from former parts of this work, that the amount of elevation here supposed to have taken place is not greater than we can prove to have occurred in other regions within geological periods of no great duration. On the other hand, the quantity of denudation or removal by water of vast masses which are assumed to have once reached continuously from the North to the South Downs is so enormous, that the reader may at first be startled by the boldness of the hypothesis. But he will find the difficulty to vanish when once sufficient time is allowed for the gradual and successive rise of the strata, during which the waves and currents of the ocean might slowly accomplish an operation, which no sudden diluvial rush of waters could possibly have effected.

Escarpments of the chalk once sea-cliffs.—In order to make the reader acquainted with the physical structure of the Valley of the Weald, I shall suppose him first to travel southwards from the London basin. On leaving the tertiary strata he will first ascend a gently inclined plane, composed of the upper flinty portion of the chalk, and then find himself on the summit of a declivity consisting, for the most part, of different members of the chalk formation; below which the upper green-sand, and sometimes also the gault, *crop out.** This steep declivity is called by geologists "the escarpment of the chalk," which overhangs a valley excavated chiefly out of the argillaceous or marly bed, termed Gault (No. 2.). The escarpment is continuous along the southern termination of the North Downs, and may be traced from the sea at Folkstone, west-

* This term, borrowed from our miners, is used to express the coming up to the surface of one stratum from beneath another.

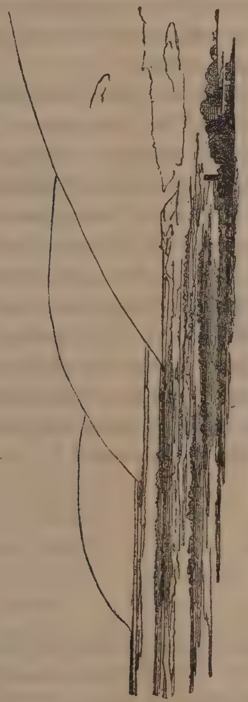
Fig. 135.

View of the chalk escarpment of the South Downs. Taken from the Devil's Dike, looking towards the west and south-west.

a. The town of Steyning is hidden by this point. *b.* Edburton church. *c.* Road. *d.* River Adur.

ward to Guildford and the neighbourhood of Petersfield, and from thence to the termination of the South Downs at Beachy Head. In this precipice or steep slope the strata are cut off abruptly, and it is evident that they must originally have extended farther. In the accompanying wood-cut (Fig 135.), part of the escarpment of the South Downs is faithfully represented, where the denudation at the base of the declivity has been somewhat more extensive than usual, in consequence of the upper and lower green-sand being formed of very incoherent materials, the upper, indeed, being extremely thin and almost wanting.

Fig. 136.



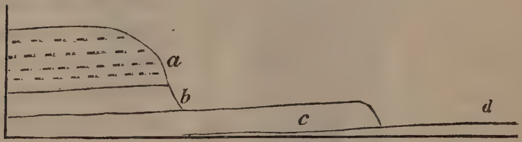
Chalk escarpment as seen from the hill above Steyning, Sussex. The castle and village of Bramber in the foreground.

The geologist cannot fail to recognize in this view the exact likeness of a sea-cliff; and if he turns and looks in an opposite direction, or eastward, towards Beachy Head (see Fig. 136.), he will see the same line of height prolonged. Even those who are not accustomed to speculate on the former changes which the

surface has undergone may fancy the broad and level plain to resemble the flat sands which were laid dry by the receding tide, and the different projecting masses of chalk to be the headlands of a coast which separated the different bays from each other.

Lower terrace of firestone.—I have said that the upper green-sand ("firestone," or "malm-rock," as it is sometimes called) is almost absent in the tract here alluded to. It is, in fact, seen at Beachy Head to thin out to an inconsiderable stratum of loose green-sand; but farther to the westward it is of great thickness, and contains hard beds of blue chert and limestone. Here, accordingly, we find that it produces a corresponding influence on the scenery of the country; for it runs out like a step beyond the foot of the chalk-hills, and constitutes a lower terrace, varying in breadth from a quarter of a mile to three miles, and following the sinuosities of the chalk escarpment.*

Fig. 137.



a. Chalk with flints. *b.* Chalk without flints.
c. Upper green-sand, or firestone. *d.* Gault.

It is impossible to desire a more satisfactory proof that the escarpment is due to the excavating power of water during the rise of the strata; for I have shown, in my account of the coast of Sicily, in what manner the encroachments of the sea tend to efface that suc-

* Mr. Murchison, Geol. Sketch of Sussex, &c., Geol. Trans., Second Series, vol. ii. p. 98.

cession of terraces which must otherwise result from the successive rises of a coast preyed upon by the waves.* During the interval between two elevatory movements, the lower terrace will usually be destroyed, wherever it is composed of incoherent materials; whereas the sea will not have time entirely to sweep away another part of the same terrace, or lower platform, which happens to be composed of rocks of a harder texture, and capable of offering a firmer resistance to the erosive action of water.

Valleys where softer strata, ridges where harder crop out.—It is evident that the gault No. 2. (see the map) could not have opposed any effectual resistance to the denuding force of the waves; its outcrop, therefore, is marked by a valley, the breadth of which is often increased by the loose incoherent nature of the uppermost beds of the lower green-sand, which lie next to it, and which have often been removed with equal facility.

This formation (the lower green-sand) has been sometimes entirely smoothed off like the gault; but in those districts where chert, limestone, and other solid materials enter largely into its composition, it forms a range of hills parallel to the chalk, which sometimes rival the escarpment of the chalk itself in height, or even surpass it, as in Leith Hill. This ridge often presents a steep escarpment towards the Weald clay which crops out from under it. (See the strong lines in Fig. 133. p. 237.)

The clay last mentioned forms, for the most part, a broad valley, separating the lower green-sand from the Hastings sands, or Forest ridge; but where subordinate

* See p. 8. and wood-cut No. 87.

beds of sandstone of a firmer texture occur, the uniformity of the plain is broken by waving irregularities and hillocks.*

In the central region, or Forest ridge, the strata have been considerably disturbed, and are greatly fractured and shifted. One fault is known where the vertical shift of a bed of calcareous grit is no less than sixty fathoms.† It must not be supposed that the anticlinal axis, which is described as running through the centre of the Weald, is by any means so simple as is usually represented in geological sections. There are, on the contrary, a series of anticlinal and synclinal‡ lines, which form ridges and troughs running nearly parallel to each other.

Much of the picturesque character of the scenery of this district arises from the depth of the narrow valleys and ridges to which the sharp bends and fractures of the strata have given rise; but it is also in part to be attributed to the excavating power exerted by water, especially on the interstratified argillaceous beds.

From the above description it will appear that, in the tract intervening between the North and South Downs, there are a series of parallel valleys and ridges; the valleys appearing evidently to have been formed principally by the removal of softer materials, while the ridges are due to the resistance offered by firmer beds to the destroying action of water.

Rise and denudation of the strata gradual. — Let us then consider how far these phenomena agree with the

* Martin, Geol. of Western Sussex. Fitton, Geol. of Hastings, p. 31.

† Fitton, Ibid. p. 55.

‡ For explanation of these terms, see Glossary, Vol. I.

changes which we should naturally expect to occur during the rise of the secondary strata. Suppose the line of the most violent movements to have coincided with what is now the central ridge of the Weald valley; in that case the first land which emerged must have been situated where the Forest ridge is now placed. Here a number of reefs may have existed, and islands of chalk, which may have been gradually devoured by the ocean in the same manner as Heligoland and other

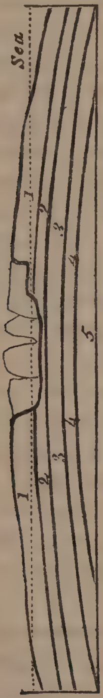


Fig. 138.

Fig. 139.

The dotted lines represent the sea-level.

European islands have disappeared in modern times, as related in the second book.*

Suppose the ridge or dome first elevated to have been so rent and shattered on its summit as to give more easy access to the waves, until at length the masses represented by the fainter lines (Fig. 138.) were removed. Two strips of land might then remain on each side of a channel, in the same manner as the opposite coasts of France and England, composed of chalk, present ranges of white cliffs facing each other. A powerful current might then rush, like that which now ebbs and flows through the Straits of Dover, and might scoop out a channel in the gault. We must bear in mind that the intermittent action of earthquakes would accompany this denuding process, fissuring rocks, throwing down cliffs, and bringing up, from time to time, new stratified masses, and thus greatly accelerating the rate of waste. If the lower bed of chalk on one side of the channel should be harder than on the other, it would cause an under terrace, as represented in the diagram (Fig. 138.), resembling that presented by the upper green-sand in parts of Sussex and Hampshire. When at length the gault was entirely swept away from the central parts of the channel, the lower green-sand (3. Fig. 139.) would be laid bare, and portions of it would become land during the continuance of the upheaving earthquakes. Meanwhile the chalk cliffs would recede farther from one another, whereby four parallel strips of land, or perhaps rows of islands, would be caused.

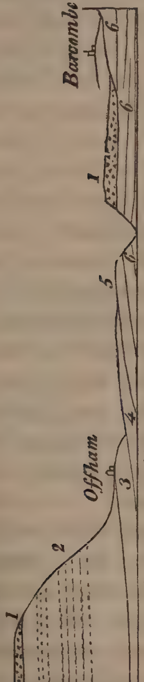
By a continuance of these operations the edges of the argillaceous strata, No. 2. (Fig. 139.), would be ex-

* Vol. II. p. 58.

posed to farther erosion by the waves, and a portion of the clay, No. 4., would be also removed, and as it gradually rose, would be swept off from part of the subjacent group, No. 5. This last would then in its turn be laid bare, and afterwards become land by subsequent elevation.

Why no ruins of chalk on central district. — By this theory of the successive emergence and denudation of the groups, 1, 2, 3, 4, 5., we may account for an alluvial phenomenon which seems inexplicable on any other hypothesis. The summits of the chalk downs are covered every where with flint gravel, which is often entirely wanting on the surface of the clay at the foot of the chalk escarpment, and no traces of chalk flint have ever been found in the alluvium of the central district, or Forest ridge. It is rare, indeed, to see any wreck of the chalk, even at the distance of two or three miles from the escarpments of the North and South Downs, a fact attested by those road-surveyors who have diligently sought for such materials. To this general rule, however, an exception occurs near Barcombe,

Fig. 140.



Section from the North escarpment of the South Downs to Barcombe.

1. Gravel composed of partially rounded chalk flints.
2. Chalk with and without flints.
3. Lowest chalk or chalk marl (upper green-sand wanting).
4. Gault.
5. Lower green-sand.
6. Weald clay.

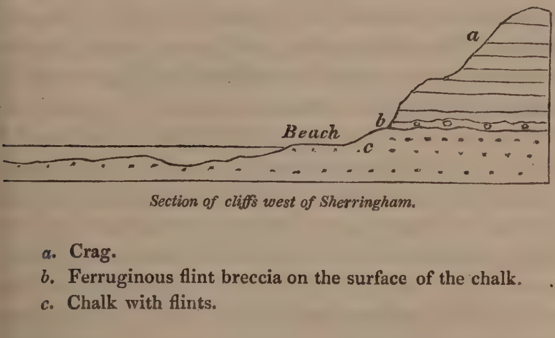
about three miles to the north of Lewes, a place which I visited with Mr. Mantell, to whom I am indebted for the accompanying section (Fig. 140.). It will be seen that the valley at the foot of the escarpment extends, in this case, not only over the gault, but over the "lower green-sand" to the Weald clay. On this clay a thick bed of flints, evidently derived from the waste of chalk, remains in the position above described.

When I say that there is no detritus of the chalk and its flints on the central ridge of the Weald, I may state that I have sought in vain for a vestige of such fragments; and Mr. Mantell, who has had greater opportunities of minute investigation, assures me that he has never been able to detect any. Now, whether we embrace or reject the theory of the former continuity of the chalk and other groups over the whole space intervening between the North and South Downs, we certainly cannot imagine that any transient and tumultuous rush of waters could have swept over this country, which should not have left some fragments of the chalk and its flints in the deep valleys of the Forest ridge. Indeed, if we adopt the diluvial hypothesis of Dr. Buckland, we should expect to find vast heaps of broken flints drifted frequently into the valleys of the Gault and Weald clay, instead of being generally confined to the summit of the chalk downs.

On the other hand, it is quite conceivable that the slow agency of oceanic currents may have cleared away, in the course of ages, the matter which fell into the sea from wasting cliffs. But in order that this explanation should be satisfactory we must suppose that the rise of the land in the south-east of England was very gradual, and the subterranean movements for the most part of moderate intensity. During the last cen-

tury earthquakes have occasionally thrown down at once whole lines of sea-cliffs, for several miles continuously; but if this had happened repeatedly during the waste of the ancient escarpments of the chalk now encircling the Weald, and if the shocks had been accompanied by the sudden rise and conversion of large districts into land, the Weald would have been covered with the ruins of those wasted rocks, and the sea could not possibly have had time to clear the whole away. The reader will recollect the account before given of the manner in which the sea has advanced, within the last century, upon the Norfolk coast at Sherringham.*

Fig. 141.



Section of cliffs west of Sherringham.

a. Crag.
b. Ferruginous flint breccia on the surface of the chalk.
c. Chalk with flints.

The beach, at the foot of the cliff, is composed of bare chalk with flints, as is the bed of the sea near the shore. No one would suspect, from the appearance of the beach at low water, that a few years ago beds of solid chalk, together with sand and loam of the superincumbent crag, formed land on the very spot where the waves are now rolling; still less that these

* Vol. II. p. 25.

same formations extended, within the last fifty years, to a considerable distance from the present shore, over a space where the sea has now excavated a channel twenty feet deep.

As in this recent instance the ocean has cleared away part of the chalk, and its capping of crag, so the tertiary sea may have swept away not only the chalk surrounding the valley of the Weald, but the layer of broken flints on its surface, which was probably a marine alluvium of the Eocene period. Hence these flints might naturally occur on the downs, and be wanting in the valleys below.

If the reader will refer to the preceding diagrams (Figs. 138. and 139. p. 245.), and reflect not only on the successive states of the country there delineated, but on all the intermediate conditions which the district must have passed through during the process of gradual elevation and denudation before supposed, he will understand why no wreck of the chalk (No. 1.) should occur at great distances from the chalk escarpments; for it is evident that when the ruins of the uppermost bed (No. 1. Fig. 138.) had been thrown down upon the surface of the bed immediately below, those ruins would subsequently be carried away when this inferior stratum itself was destroyed. And in proportion to the number and thickness of the groups, thus removed in succession, is the probability lessened of our finding any remnants of the highest group strewed over the bared surface of the lowest.

Transverse valleys.—There is another peculiarity in the geographical features of the south-east of England, which must not be overlooked when we are considering the action of the denuding causes. By reference to the map (Plate XV.), the reader will perceive that

the drainage of the country is not effected by water-courses following the great valleys excavated out of the argillaceous strata (Nos. 2. and 4.), but by valleys which run in a transverse direction, passing through the chalk to the basin of the Thames on the one side, and to the English Channel on the other.

In this manner the chain of the North Downs is broken by the rivers Wey, Mole, Darent, Medway, and Stour; the South Downs by the Arun, Adur, Ouse and Cuckmere.*

If these transverse hollows could be filled up, all the rivers, observes Mr. Conybeare, would be forced to take an easterly course, and to empty themselves into the sea by Romney Marsh and Pevensey levels.†

Mr. Martin has suggested that the great cross fractures of the chalk, which have become river channels, have a remarkable correspondence on each side of the valley of the Weald; in several instances the gorges in the North and South Downs appearing to be directly opposed to each other. Thus, for example, the defiles of the Wey, in the North Downs, and of the Arun in the South, seem to coincide in direction; and, in like manner, the Ouse corresponds to the Darent, and the Cuckmere to the Medway.‡

Although these coincidences may, perhaps, be accidental, it is by no means improbable, as hinted by the author above mentioned, that the great amount of elevation towards the centre of the Weald district gave rise to transverse fissures. And as the longitudinal valleys were connected with that linear movement which caused the anticlinal lines running east and west, so

* Conybeare, Outlines of Geol., p. 81. † Ibid., p. 145.

‡ Geol. of Western Sussex, p. 61.

Fig. 142.

Transverse Valley of the Adur in the South Downs.

a. Town of Steyning. *b.* River Adur. *c.* Old Shoreham.

the cross fissures might have been occasioned by the intensity of the upheaving force towards the centre of the line, whereby the effect of a double axis of elevation was in some measure produced.

In order to give a clearer idea of the manner in which the chalk-hills are intersected by these transverse valleys, I subjoin a sketch (Fig. 142.) of the gorge of the river Adur, taken from the summit of the chalk downs, at a point in the bridle-way leading from the towns of Bramber and Steyning to Shoreham. If the reader will refer again to the view given in a former wood-cut (Fig. 135. p. 240.), he will there see the exact point where the gorge, of which I am now speaking, interrupts the chalk escarpment. A projecting hill, at the point *a*, hides the town of Steyning, near which the valley commences where the Adur passes directly to the sea at Old Shoreham. The river flows through a nearly level plain, as do most of the others which intersect the hills of Surrey, Kent, and Sussex; and it is evident that these openings, so far at least as they are due to aqueous erosion, have not been produced by the rivers, many of which, like the Ouse near Lewes, have filled up arms of the sea, instead of deepening the hollows which they traverse.

In regard to the origin of the transverse ravines,

Fig. 143.

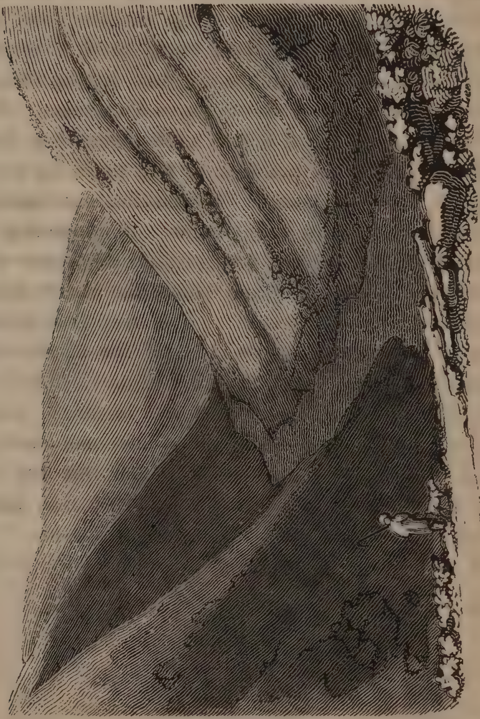
Supposed section of Transverse Valley.

there can be no doubt that they are connected with lines of fracture, and perhaps, in some places, there

may be an anticlinal dip on both sides of the valley, as suggested by Mr. Martin.* But this notion requires confirmation.

The ravine, called the Coomb, near Lewes, affords a beautiful example of the manner in which narrow

Fig. 144.



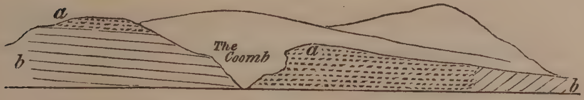
The Coomb, near Lewes.

openings in the chalk may have been connected with shifts and dislocations in the strata. This coomb is

* Geol. of Western Sussex, p. 64. Plate III. fig. 3.

seen on the eastern side of the valley of the Ouse, in the suburbs of the town of Lewes. The steep declivities on each side are covered with green turf, as is the bottom, which is perfectly dry. No outward signs of disturbance are visible; and the connexion of the hollow with subterranean movements would not have been suspected by the geologist, had not the evidence of great convulsions been clearly exposed in the escarpment of the valley of the Ouse, and in the numerous chalk pits worked at the termination of the Coomb. By aid of these we discover that the ravine coincides precisely with a line of fault, on one side of which the chalk with flints, *a*, appears at the summit of a hill, while it is thrown down to the bottom on the other. I examined this spot in company with Mr. Mantell, to whom I am indebted for the accompanying section.

Fig. 145.



Fault in the cliff-hills near Lewes.

a. Chalk with flints. *b.* Lower chalk.*

The fracture here alluded to is one of those which run east and west, and of which there are many in the Weald district, parallel to the central axis of the Forest ridge.

In whatever manner the transverse gorges originated, they must evidently have formed ready channels of communication between the submarine longitudinal

* For farther information, see Mantell's Geol. of S. E. of England, p. 352.

valleys and those deep parts of the sea wherein the tertiary strata may have accumulated. If the strips of land which first rose had been unbroken, and there had been no free passage through the cross fractures, the currents would not so easily have drifted away the materials detached from the wasting cliffs, and it would have been more difficult to understand how the wreck of the denuded strata could have been so entirely swept away from the base of the escarpments.

In the next chapter I shall resume the consideration of these subjects, especially the proofs of the former continuity of the chalk of the North and South Downs, and the probable connexion of the denudation of the Weald valley with the origin of the Eocene strata.

CHAPTER XXII.

ORIGIN OF THE ENGLISH EOCENE FORMATIONS AND DENUDATION OF THE WEALD — *continued*.

The alternative of the proposition that the chalk of the North and South Downs was once continuous, considered — Dr. Buckland on Valleys of Elevation (p. 259.) — If rise and denudation of secondary rocks gradual, so also the deposition of tertiary strata (p. 267.) — Composition of the latter such as would result from wreck of denuded secondary rocks — Central parts of the London and Hampshire basins nearly as high as Weald — Why — Curved and vertical strata in the Isle of Wight — Eocene alluviums (p. 276.) — Formation of valleys — Recapitulation.

Extent of denudation in the Valley of the Weald.— "It would be highly rash," observes Mr. Conybeare, speaking of the denudation of the Weald, "to assume that the chalk at any period actually covered the whole space in which the inferior strata are now exposed, although the truncated form of its escarpment evidently shows it to have once extended much farther than at present." *

I believe that few geologists who have considered the extent of country supposed to have been denuded, and who have explored the hills and valleys of the central or Forest ridge, without being able to discover the slightest vestige of chalk in the alluvium †, will fail to participate, at first, in the doubts here expressed

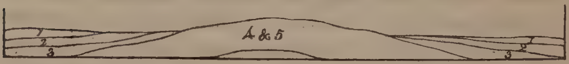
* Outlines, p. 144.

† See above, p. 247.

as to the original continuity of the upper secondary formations over the anticlinal axis of the Weald. For my own part, I never traversed the wide space which separates the North and South Downs, without desiring to escape from the conclusions advocated in the last chapter; and yet I have been invariably brought back again to the opinion, that the chalk was originally continuous, on a more deliberate review of the whole phenomena.

It may be useful to consider the only other alternative of the hypothesis before explained. If the marine groups, Nos. 1, 2, 3., were not originally con-

Fig. 146.



1. Chalk and Upper green-sand. 2. Gault. 3. Lower green-sand.	Marine.	4. Weald clay. 5. Hastings sands.	Fresh-water.

tinuous, it is necessary to imagine that they each terminated at some point between their present outgoings and the secondary strata of the Forest ridge. Thus we might suppose them to have thinned out one after the other, as in the above diagram, and never to have covered the entire area occupied by the freshwater strata, Nos. 4. and 5.

It must be granted, that had such been the original disposition of the different groups, they might, as they gradually emerged from the sea, have become denuded in the manner explained in the last chapter, so that the country might equally have assumed its present configuration. But, although I know of no invincible objection to such an hypothesis, there are certainly no

appearances which favour it. If the strata Nos. 4. and 5. had been unconformable to the lower green-sand No. 3., then, indeed, we might have imagined that the older groups had been disturbed by a series of movements antecedently to the deposition of No. 3.; and, in that case, some parts of them might be supposed to have emerged or formed shoals in the ancient sea, interrupting the continuity of the newer marine deposits. But the group No. 4. is *conformable* to No. 3.; and the only change which has been observed to take place at the junction is an occasional intermixture of the Weald clay with the superior marine sand, such as might have been caused by a slight superficial movement in the waters when the sea first overflowed the fresh-water strata.

On the other hand, the green-sand and chalk, as they approach the central axis of the Weald, are not found to contain littoral shells, or any wreck of the fresh-water strata, such as might indicate the existence of an island with its shores or wasting cliffs. Had any such signs been discovered, we might have supposed the geography of the region to have once borne some resemblance to that exhibited in the diagram Fig. 146.

Dr. Buckland on Valleys of Elevation.—We are indebted to Dr. Buckland for an able memoir in illustration of several districts of similar form and structure to the Weald, which occur at no great distance in the south of England. His paper is intitled, "On the Formation of the Valley of Kingsclere and other Valleys by the Elevation of the Strata which inclose them." *

* Geol. Trans., Second Series, vol. ii. p. 119.

The valley of Kingsclere, a few miles south of Newbury, in Berkshire, is about five miles long and two in breadth. The upper and lower chalk (see Fig. 149.*) and the upper green-sand dip in oppositedir ections from an anticlinal axis which passes through the middle of the valley along the line *a*, *b*, of the ground-plan (Fig. 147.).

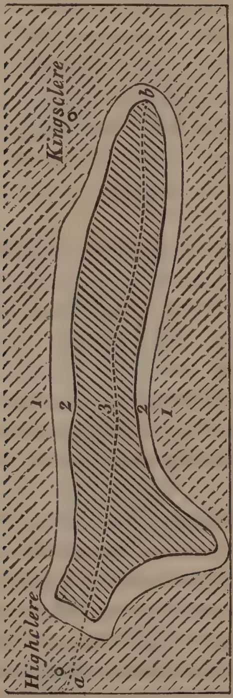


Fig. 147.

Valley of Kingsclere.

a, *b*. Anticlinal line marking the junction of the opposite dip of the strata on on each side of it.

Fig. 148.

Valley of Kingsclere.

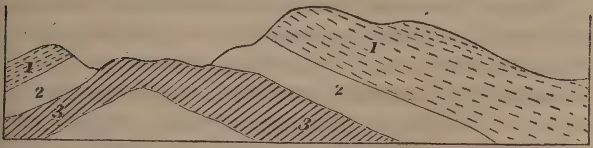
In the wood cut (Fig. 148.) the scale of heights

* Copied by permission from Dr. Buckland's Plate XVII., Geol. Trans., Second Series, vol.ii.

more nearly approaches to that of nature, although the altitudes, in proportion to the horizontal extent, are even in this, perhaps, somewhat in excess. On each side of the valley we find escarpments of chalk, the strata of which dip in opposite directions, in the northern escarpment to the north, and in the southern to the south. At the eastern and western extremities of the valley, the two escarpments become confluent, precisely in the same manner as do those of the North and South Downs, at the eastern end of the Weald district, near Petersfield. And as, a few miles east of the town last mentioned (see Map, Plate XV.), the firestone, or upper green-sand, is laid open in the sharp angle between the escarpment of the Alton Hills and the western termination of the South Downs * ; so in the valley of Kingsclere the same formation is seen to crop out from beneath the chalk.

The reader might imagine, on regarding the section (Fig. 149.), where, for the sake of elucidating the geo-

Fig. 149.



Section across the Valley of Kingsclere from north to south.

1. Chalk with flints. 2. Lower chalk without flints.
3. Upper green-sand, or firestone, containing beds of chert.

N.B. The lines here are not intended to represent strata.

logical phenomena, the heights are exaggerated in proportion to the horizontal extent, that the solution of

* See Mr. Murchison's Map, Plate XIV., Geol. Trans., Second Series, vol. ii.

continuity of the strata bounding the valley of Kingsclere had been simply due to elevation and fracture, unassisted by aqueous causes; but by reference to the truer scale (Fig. 148.), it will immediately appear that a considerable mass of chalk must have been removed by denudation.

If the anticlinal dip had been confined to the valley of Kingsclere, we might have supposed that the upheaving force had acted on a mere point, forcing upwards the superincumbent strata into a small dome-shaped eminence, the crown of which had been subsequently cut off; but Dr. Buckland traced the line of opposite dip far beyond the confluence of the chalk escarpments, and found that it was prolonged in a more north-west direction far beyond the point *a* (Fig. 147.). In following the line thus extended, the strata are seen in numerous chalk-pits to have an opposite dip on either side of a central axis, from which we may clearly infer the linear direction of the movement.

Many of the valleys having a similar conformation to that of Kingsclere, run east and west, like the anticlinal ridge of the Weald valley. Several of these occur in Wiltshire and Dorsetshire, and they are all circumscribed by an escarpment whose component strata dip outwards from an anticlinal line running along the central axis of the valley. One of these, distant about seven miles to the north-east of Weymouth, is nearly elliptical in shape, and in size does not much exceed the Coliseum at Rome. Their drainage is generally effected in a manner analogous to the drainage of the Weald, by an aperture in one of their lateral escarpments, and not at either extremity of their longer

axis, as would have happened had they been simply excavated by the sweeping force of rapid water.*

"It will be seen," continues Dr. Buckland, "if we follow on Mr. Greenough's map the south-western escarpment of the chalk in the counties of Wilts and Dorset, that, at no great distance from these small elliptical valleys of elevation, there occur several longer and larger valleys, forming deep notches, as it were, in the lofty edge of the chalk. These are of similar structure to the smaller valleys we have been considering, and consist of green-sand, inclosed by chalk at one extremity, and flanked by two escarpments of the same, facing each other with an opposite dip; but they differ in the circumstance of their other and broader extremity being without any such inclosure, and gradually widening till it is lost in the expanse of the adjacent country.

"The cases I now allude to are the Vale of Pewsey, to the east of Devizes; that of the Wily, to the east of Warminster; and the Valley of the Nadder, extending from Shaftesbury to Barford, near Salisbury; in which last not only the strata of green-sand are brought to the surface, but also the still lower formations of Purbeck and Portland beds, and of Kimmeridge clay.

"It might at first sight appear that these valleys are nothing more than simple valleys of denudation; but the fact of the strata composing their escarpments having an opposite and outward dip from the axis of the valley, and this often at a high angle, as near Fonthill and Barford, in the Vale of the Nadder, and at Oare, near the base of Martinsell Hill, in the

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 122.

Vale of Pewsey, obliges us to refer their inclination to some antecedent violence, analogous to that to which I have attributed the position of the strata in the inclosed valleys near Kingsclere, Ham, and Burbage. Nor is it probable that, without some pre-existing fracture or opening in the lofty line of the great chalk escarpment, which is here presented to the north-west, the power of water alone would have forced open three such deep valleys as those in question, without causing them to maintain a more equable breadth, instead of narrowing till they end in a point in the body of the chalk."*

Now, in the Weald, the strata of the North Downs are inclined to the north at an angle of from 10° to 15°, or even 45°, in the narrow ridge of the Hog's Back, west of Guildford, in Surrey; while those in the South Downs dip to the south at a slight angle. It is superfluous to dwell on the analogy which, in this respect, the two escarpments bear to those which flank the valleys above alluded to; and in regard to the greater distance which separates the hills of Surrey from those of Sussex, the difficulty may be reduced simply to a question of time.

If the rise of the land was accomplished by an indefinite number of minor convulsions, or by a slow and insensible upheaving like that now taking place in Sweden, the power of the ocean would be fully adequate to perform the work of denudation in the lapse of many ages. If, on the other hand, we embrace the hypothesis of paroxysmal elevation; or, in other words, suppose a submarine tract to have been converted instantaneously into high land, we may seek in vain

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 123.

for any known cause capable of sweeping away even those portions of chalk and other rocks which, all are agreed, must once have formed the prolongation of the existing escarpments. It is common in such cases to call in one imaginary cause to support another; and as the upheaving force operated with sudden violence, so a vast diluvial wave is introduced to carry away, with almost equal celerity, the mountain mass of strata assumed to have been stripped off.

Some geologists have endeavoured to account for the structure of the districts described as "valleys of elevation," by the aid of Von Buch's theory of "elevation craters," in which case they can dispense both with time and denudation. It would be superfluous to repeat what has been already said of the hypothetical agency here referred to*; but it may be well to consider whether the upheaving of small dome-shaped masses, such as those described by Dr. Buckland, implies the development at a considerable depth of volcanic forces acting with great violence on limited areas, or mere points of the earth's crust.

A theory suggested by Dr. Fitton appears to me far more probable. Suppose a series of horizontal strata, composed in great part of sand and soft clay, to repose on a foundation of older and more solid rocks presenting an uneven surface, varied by hills, valleys, and ridges, like many parts of the land and bed of the sea. If a force acting from beneath should then elevate the whole mass, the protuberances of the subjacent rocks would be forced up against the more compressible strata which covered them. The effect of the pressure

* Vol. II. p. 205.

might be the same as that which happens on a small scale in a bound book, when a minute inequality or knob in the paper of some page is propagated through a great number of others, imparting its shape to all, without piercing through them.* The observations of Dolomieu on the manner in which the more yielding tertiary strata of Calabria were displaced by the granite during the earthquake of 1783, lends some countenance to this theory.†

In the last chapter I pointed out the phenomena which seem to indicate that the elevation and denudation of land in the south-east of England were gradual.‡ The same arguments are in a great degree applicable to the basins of Hampshire and the Isle of Wight; but Mr. Conybeare has contended that the verticality of the strata in the Isle of Wight and in Purbeck compels us to admit that the movement there was so violent, that the vertical strata, which have been traced through a district nearly sixty miles in length, were brought into their present position by a *single convulsion*.

It may well be asked what ground is there for assuming that a *single* effort of the subterranean force, rather than reiterated movements, produced that sharp flexure of which the verticle strata of the Isle of Wight are supposed to form a part, the remainder of the arc having been carried away by denudation?§

It is not improbable that the Cutch earthquake of 1819, before alluded to, may have produced an incipient curve, running in a linear direction through

* Dr. Fitton, Geol. Trans., Second Series, vol. iv. p. 244. 1834.

† See above, Vol. II. p. 258. ‡ Page 244.

§ See Webster, Englefield's Isle of Wight, Plate XLII. fig. 1.

a tract at least sixty miles in length.* The strata were upraised in the Ullah Bund, and depressed below the level of the sea in the adjoining tract, where the fort of Sindree was submerged. (See Plate V.) It would be impossible, if the next earthquake should raise the Bund still higher, and sink to a lower depth the adjoining tract, to discriminate, by any geological investigations, the different effects of the two earthquakes, unless a minute survey of the effects of the first shock had been made and put on record. In this manner we may suppose the strata to be bent again and again, in the course of future ages, until parts of them become perpendicular.

To some it may appear that there is a unity of effect in the line of deranged strata in the Isles of Wight and Purbeck, as also in the central axis of the Weald, which is inconsistent with the supposition of a great number of separate movements recurring after long intervals of time. But we know that earthquakes are repeated throughout a long series of ages, in the same spots, like volcanic eruptions. The oldest lavas of Etna were poured out many thousands, perhaps myriads, of years, before the newest, and yet they have produced a symmetrical mountain; and if rivers of melted matter thus continue to flow in the same direction, and towards the same points, for an indefinite lapse of ages, what difficulty is there in conceiving that the subterranean volcanic force, occasioning the rise or fall of certain parts of the earth's crust, may, by reiterated movements, produce the most perfect unity of result?

If denudation of secondary rocks gradual, so also deposition of tertiary.—It follows then, from the facts

* See Vol. II. p. 237., and Vol. III. p. 273.

examined in this and the preceding chapter, that subsequently to the deposition of the chalk a large region composed of secondary strata has been denuded, and that the lapse of many ages must have been required for the entire removal of the materials from the denuded district.

It is no less evident that the transported matter must have been deposited by degrees somewhere else. Are there any tracts in the south-east of England, where we find derivative strata composed of a mixture of such mineral ingredients as would result from the degradation of the secondary groups Nos. 1, 2, 3, 4, 5? The tertiary strata of the London and Hampshire basins answer well to the conditions required by such an origin, for they consist of alternations of variously coloured sands and clays, as do the secondary strata from the group No. 5. to No. 2. inclusive. Some tertiary green-sand, which occurs in parts of the plastic clay formation in the basins of London and Hants, cannot be distinguished mineralogically from a large part of that which is found in the secondary formations below the chalk.

If it be asked, where do we find the ruins of the *white chalk* among our Eocene strata?—The answer is, first, that the flint pebbles, which are associated in such immense abundance with the sands of the plastic clay, are derived evidently from the destruction of chalk, and contain the same fossils: secondly, that as to the soft, white, calcareous matrix, we may suppose it to have been easily reduced to fine sediment, and to have contributed, when in a state of perfect solution, to form the shells of Eocene testacea; or when mixed with the waste of the argillaceous groups, Nos. 2. and 4., which have been peculiarly exposed to denudation, it

may have entered into the composition of the London clay, which contains no slight proportion of calcareous matter. In the *crag* of Norfolk, undoubtedly, we find great heaps of broken pieces of white chalk, with slightly worn and angular flints ; but, in this case, we may infer that the attrition was not continued for a long time ; whereas, the large accumulations of perfectly rolled shingle, which are interstratified with our Eocene formations, proves that they were acted upon for a protracted period by the waves. We have many opportunities of witnessing the entire demolition of the chalk on our southern coast, as at Seaford, for example, in Sussex, where large masses are, year after year, detached from the cliffs, and soon disappear, leaving nothing behind but a great bank of flint shingle.*

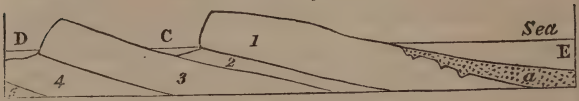
It may also be remarked that the white chalk in the north of England, as in Yorkshire, for example, is much harder than the corresponding formation in the southern counties, where it is now so soft that we may imagine it to have been in the state of mud when submerged beneath the waters of the sea. An original difference of this kind in the degree of induration may explain the fact, that in certain districts gravel composed of chalk-flint occurs without any pebbles of white chalk, while in other regions rounded boulders of white chalk are plentifully intermixed with pebbles of flint.

The similarity, then, of the mineral ingredients of the Eocene secondary strata affords alone some pre sumption in favour of this newer group having been derived from the wreck of the older series. But it is also natural to expect, that when the formations of the Weald were emerging, there would be some contiguous

* Vol. II. p. 43.

parts of the sea sufficiently deep to receive the drift matter.

Fig. 150.



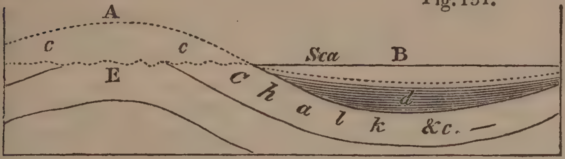
We may suppose, that while the waves and currents were excavating the longitudinal valleys, D and C (Fig. 150.), "the deposits *a* were thrown down to the bottom of the contiguous deep water E, the sediment being drifted through transverse fissures, as before explained. In this case, the rise of the formations Nos. 1, 2, 3, 4, 5, may have been going on contemporaneously with the excavation of the valleys C and D, and with the accumulations of the strata *a*. There must be innumerable points on our own coast where the sea is of great depth near to islands and cliffs now exposed to rapid waste, and in all these the denuding and reproductive processes must be going on in the immediate proximity of each other.

English Eocene strata rise nearly as high as the denuded secondary districts.—Those geologists who have hitherto regarded the rise and denudation of the lands in the south-east of England as events altogether posterior in date to the deposition of the London clay, will object to the foreging reasoning, that not only certain outlying patches of tertiary strata, but even the central parts of the London and Hampshire basins, attain very considerable altitudes above the level of the sea. Thus the London clay at Highbeach, in Essex, reaches the height of 750 feet; an elevation exceeding that of large districts of the chalk and other

denuded secondary rocks. But these facts do not, I think, militate against the theory above proposed, since I have endeavoured to show that there must have been a long-continued series of elevatory movements in a region where both the degradation and reproduction of strata were in progress.

In order to explain this view, I shall assume that, in the region A (Fig. 151.), the chalk and associated strata

Fig. 151.



are raised and converted into land; while in the adjoining district, B, a continuous part of the same beds remains submerged beneath the sea. During the elevation in A, the mass *c c* is gradually removed by denudation, and its ruins drifted to B, forming the tertiary deposit *d*. The force of water has thus exerted an antagonist power; so that in spite of the upheaving movement, the general outline of the solid surface, or the relative levels of its various parts, are not greatly altered; for the uppermost part of the newer deposit *d* rises nearly as high as the remaining summits of the denuded country A. After all these changes and levelling operations, an elevation to the amount of eight hundred feet in both the regions A and B, would cause the secondary rocks of A to acquire much the same height above the level of the sea, as the tertiary beds would attain in B.

The estimate of Mr. Martin is not, perhaps, exaggerated, when he computes the probable thickness

of strata removed from the highest part of the Forest ridge to be about 1900 feet: so that, if we restore to Crowborough Hill, in Sussex, the beds of Weald clay, lower green-sand, gault, and chalk, which have been removed by denudation, that hill, instead of rising to the height of eight hundred feet, would be more than trebled in altitude, and be about 2700 feet high. * It would then tower far above the highest outliers of tertiary strata which are scattered over our chalk; for Inkpen Hill, in Berkshire, the greatest elevation of chalk in England, rises only 1011 feet above the level of the sea.

Some geologists, who have thought it necessary to suppose all the strata of the London and Hampshire basins to have been once continuous, have estimated the united thickness of the three marine Eocene groups before described, as amounting to 1300 feet, and have been bold enough to imagine a mass of this height to have been once superimposed upon the chalk which formerly covered the axis of the Weald.† Hence they were led to infer that Crowborough Hill was once four thousand feet high, and was then cut down from four thousand to eight hundred feet by *diluvial action.*

But by adopting the view above explained, that the Eocene deposits originated while the chalk and other secondary rocks were rising from the sea and wasting away, we shall find it unnecessary to suppose any removal of formations newer than the chalk, from the central parts of the Weald.

Vertical strata of the Isle of Wight.— A line of vertical and inclined strata, running east and west, or

* Phil. Mag. and Annals, No. 26., New Series, p. 117.

† Martin, ibid.

parallel to the central axis of the Weald, extends, as has been stated, through the Isles of Wight and Purbeck, and through Dorsetshire, and has been observed by Dr. Fitton to reappear in France, north of Boulogne. The same strata which are elevated in the Weald valley are upheaved on this line also; and in the Isle of Wight, all the tertiary strata appear to have partaken in the same movement.*

From the horizontality of the fresh-water series in Alum Bay, as contrasted with the vertical position of the marine tertiary beds, Mr. Webster was at first led very naturally to conclude, that the marine had undergone great derangement before the deposition of the fresh-water strata. It appears, however, from the subsequent observations of Professor Sedgwick†, that these appearances are deceptive; and that at the eastern extremity of the Isle of Wight, part of the fresh-water series is vertical, like the marine. Hence it is now ascertained that, as the chalk is horizontal at the southern extremity of the Isle of Wight, while it is vertical in the centre of that island, so the Eocene strata are horizontal in the north of the island, and vertical in the centre.

An important corollary is deduced from the discovery above mentioned; namely, that the convulsions which brought the Isle of Wight group into their present position were, in a great part, if not entirely, subsequent to the deposition of the fresh-water beds, or upper members of the Eocene formation. They may,

* See Mr. Webster's section, Geol. Trans., vol. ii. First Series, Plate XI.

† Anniv. Address to the Geol. Soc., Feb. 1831, p. 9. Professor Sedgwick informs me that his observations, made in 1827, have recently been confirmed by Professor Henslow.

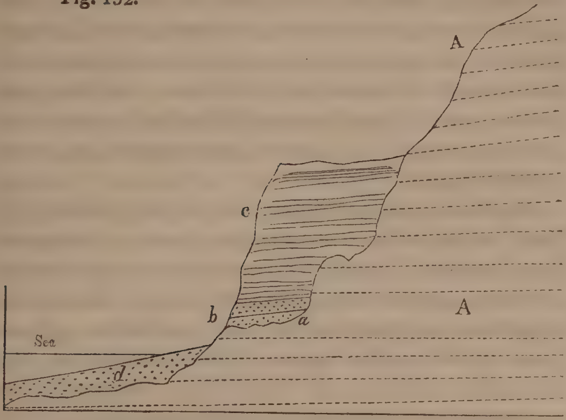
however, have been contemporaneous with those movements which raised the central parts of the London and Hampshire basins to their present height. Referring again to the diagram, Fig. 151. p. 271., we may imagine the series of elevatory movements in the S. E. of England to be divided into two parts: first, that which caused the elevation and denudation of the central axis of the Weald in A; secondly, that which uplifted the denuded surface E, together with the tertiary formations *d*, to their actual height. Now, this last set of movements may have occurred before the close of the Eocene period, and may have produced that curve in the stratified rocks of the Isle of Wight, in which the fresh-water beds there have participated.

At the same time it cannot be denied, that great movements of elevation have been experienced in the south of England since the Eocene period; as, for example, those by which the crag strata attained their present position in Norfolk, Suffolk, and Essex. The formation also called by Mr. Mantell the Elephant Bed, at the foot of the chalk cliffs at Brighton, is not merely a talus of calcareous rubble collected at the base of an inland cliff, but exhibits every appearance of having been spread out in successive horizontal layers by water in motion.

The deposit alluded to skirts the shores between Brighton and Rottingdean, and another mass apparently of the same age occurs at Dover. The phenomena appear to me to suggest the following conclusions:—First, the south-eastern part of England had acquired its actual configuration when the ancient chalk cliff A *a* was formed, the beach of sand and shingle *b* having then been thrown up at the base of

the cliff. Afterwards the whole coast, or at least that part of it where the elephant bed now extends, sub-

Fig. 152.



A. Chalk with layers of flint dipping slightly to the south.

b. Ancient beach, consisting of fine sand, from one to four feet thick, covered by shingle from five to eight feet thick of pebbles of chalk-flint, granite, and other rocks, with broken shells, &c.

c. Elephant bed, about fifty feet thick, consisting of layers of white chalk rubble, with broken chalk flints, in which deposit are found bones of ox, deer, horse, and mammoth.*

sided to the depth of fifty or sixty feet, and during the period of submergence successive layers of white calcareous rubble *c* were accumulated, so as to cover the ancient beach *b*. Subsequently, the coast was again raised, so that the ancient shore was elevated to a level somewhat higher than its original position.†

* Mantell's Geol. of S. E. of England, p. 32.

† See Mantell's Geol of S. E. of England, p. 32. After re-examining the elephant bed in 1834, I was no longer in doubt of its having been a regular subaqueous deposit.

Eocene alluviums. — The discovery, before mentioned, of the genera Palæotherium and Anoplotherium at Binstead, associated with fossil shells of well-known Eocene species, is interesting, as showing that England, or rather the space now occupied by part of our island, as well as the country of the Paris basin, and Auvergne, Cantal, and Velay, were all inhabited, during the Eocene period, by a class of land animals of a very peculiar type.

Yet we have never found a single fragment of the bones of any of these quadrupeds in our alluviums or cave breccias. In these formations we find the bones of the mastodon and mammoth, of the rhinoceros, hippopotamus, lion, hyæna, bear, and other quadrupeds, all of extinct species. Where, then, are the terrestrial alluviums of that surface which was inhabited by the Paleothere and its congeners?

It is difficult to answer this question; but it seems clear that a peculiar and rare combination of favourable circumstances is required to preserve mammiferous, or indeed any remains in terrestrial alluviums, in sufficient quantity to afford the geologist the means of assigning the date of such deposits. For this reason we are scarcely able, at present, to form any conjecture as to the relative ages of the numerous alluviums which cover the surface of Scotland; a country which probably became land long before the commencement of the tertiary epochs.

Excavation of valleys. — It will be seen that the excavation of the valleys in the S. E. of England has been referred chiefly to the ocean.

Those geologists who contend that the valleys in England are not due to what they term "modern causes," are in the habit of appealing to the fact, that

the rivers in the interior of England are working no sensible alterations, and could never, in their present state, not even in millions of years, have excavated the valleys through which they now flow. A false theory seems to be involved even in the term "modern causes," as if it could be assumed that there were *ancient causes*, differing from those which are now in operation. But if we substitute the phrase "existing causes," we shall find that the argument now controverted amounts to little more than this,—"that in a country free from subterranean movements, the action of running water is so trifling, that it could never hollow out, in any lapse of ages, a deep system of valleys, and, *therefore*, no known combination of existing causes could ever have given rise to our present valleys!"

The advocates of these doctrines, in their anxiety to point out the supposed absurdity of attributing to ordinary causes those inequalities of hill and dale, which now diversify the earth's surface, have too often kept entirely out of view the many recorded examples of elevations and subsidences of land during earthquakes; the frequent fissuring of mountains and opening of chasms; the temporary damming up of rivers by landslips, followed by their sudden and impetuous escape; the deflexion of streams from their original courses; and, more important, perhaps, than all these, the denuding power of the ocean, during the rise of continents from the deep. Few of the ordinary causes of change, whether igneous or aqueous, can be observed to act with their full intensity in any one place at the same time; hence it is easy to persuade those who have not reflected long and profoundly on the working of the numerous igneous and aqueous agents,

that they are entirely inadequate to bring about any important fluctuations in the configuration of the earth's surface.

Recapitulation. — I shall now briefly recapitulate some of the principal conclusions to which I have arrived respecting the geology of the south-east of England, in reference to the nature and origin of the Eocene formations considered in this and the two preceding chapters.

1. In the first place, it appears that the tertiary strata rest exclusively upon the chalk, and consist, with some trifling exceptions, of alternations of clay and sand.

2. The organic remains agree with those of the Paris basin; but the *mineral character* of the English tertiary deposits is extremely different, those rocks in particular which are common to the Paris basin and Central France being wanting, or extremely rare in England.

3. The English Eocene deposits are generally conformable to the chalk, being horizontal where the beds of chalk are horizontal, and vertical where they are vertical; so that both series of rocks appear to have participated in nearly the same movements.

4. It is not possible to define the limits of the ancient borders of the tertiary sea in the south-east of England, in the same manner as can be frequently done in those countries where the secondary rocks are unconformable to the tertiary.

5. Although the tertiary deposits are chiefly confined to the tracts called the basins of London and Hampshire, insulated patches of them are, nevertheless, found on some of the highest summits of the chalk intervening between these basins.

6. These outliers, however, do not necessarily prove that the great mass of tertiary strata was once continuous between the basins of London and Hampshire, and over other parts of the south-east of England now occupied by secondary rocks.

7. On the contrary, it is probable that these secondary districts were gradually elevated and denuded, when the basins of London and Hampshire were still submarine, and while they were gradually becoming filled up with tertiary sand and clay.

8. If, in illustration of this theory, we examine one of the districts thus supposed to have been denuded, we find in the valley of the Weald decided proofs, that an immense mass of chalk and other secondary formations has been removed by the force of water.

9. We may infer, from the existence in the Weald of large valleys along the outcrop of the softer beds, and of parallel chains of hills where harder rocks come up to the surface, that water was the removing cause; and from the shape of the escarpments presented by the harder rocks, and the distribution of alluvium, we may also conclude that the denudation was successive and gradual during the rise of the strata.

10. The materials carried away from the denuded districts were probably conveyed into the depths of the contiguous sea, through channels produced by cross fractures which have since become river-channels, and which now intersect the chalk in a direction at right angles to the general axis of elevation of the country.

11. The analogous structure of the valley of Kingsclere, and of other valleys which run east and west, like the valley of the Weald, but are much narrower, accords with the hypothesis, that they were all pro-

duced by the denuding power of water co-operating with elevatory movements.

12. The mineral composition of the materials thus supposed to have been removed in immense abundance from the valley of the Weald, are such as would, by degradation, form the English Eocene strata.

13. The movements which threw the chalk and the tertiary strata of the Isles of Wight and Purbeck into a vertical position, were subsequent to the formation of the Eocene fresh-water strata of the Isle of Wight, but may possibly have occurred during the Eocene period.

14. But some movements of land in the south of England must have been posterior to the deposition of the crag; and the ancient beach, together with the "elephant bed" at Brighton, seem to imply a subsidence and elevation of comparatively modern date.

15. The masses of secondary rock which have been removed by denudation from the central axis of the Weald would, if restored, rise to more than double the height now attained by any patches of tertiary strata in England.

16. If, therefore, the Eocene strata do not appear to occupy a much lower level than the secondary rocks from the destruction of which they have been formed, it is perhaps because the highest summits of the secondary formations have been cut off during the rise of the land, and thrown into those troughs where we now find the tertiary deposits.

CHAPTER XXIII.

FORMATIONS COMMONLY CALLED SECONDARY AND TRANSITION.

Ancient and modern classification of fossiliferous strata — Formations commonly called secondary and transition — The divisions usually adopted not of equivalent value — Sketch of the principal groups — Cretaceous group (p. 284.) — No species common to the secondary and tertiary rocks — Chasm between the Eocene and Maestricht beds — Duration of secondary periods — Wealden strata — Their relation to the marine groups above and below — Portland "dirt bed" — Oolitic group (p. 298.) — Lias — New red sandstone — Zechstein — Carboniferous group — Old red sandstone — Transition formations — Rock called Greywacké.

It was stated in a former chapter that the first rude attempt to classify rocks in chronological order was that according to which they were arranged in four groups called primitive, transition, secondary, and tertiary—the transition and secondary comprising all the stratified fossiliferous formations older than the tertiary. These ancient divisions, although not yet obsolete, have gradually become less and less fitted to represent the present state of our knowledge. It was never supposed that each of the four sections were of equivalent importance, or, in other words, that that they each comprised a series of monuments relating to equal portions of the ancient history of the earth. It was, however, imagined that they followed each other in

regular chronological order, and that the primary were always older than the transition; that the transition were more ancient than the secondary, and the secondary than the tertiary strata. That this opinion, though generally correct, is not strictly true in regard to the entire series called "primary," whether stratified or unstratified, will appear in the sequel.*

The fossiliferous strata have been variously grouped, according to the comparative value which different geologists have attached to different characters; some having been guided chiefly by the thickness, geographical extent, and mineralogical composition of particular sets of strata; others, by their organic remains. All, however, seem now agreed that it is by a combination of these characters that we must endeavour to decide which sets of strata should be entitled to rank as principal and independent groups. The following is an outline of the arrangement adopted in this work, which will be more fully explained by the Tables at the end of this and the 27th chapter: —

1. Tertiary, or supracretaceous † -	Tertiary.
2. Cretaceous - - - -	Secondary.
3. Wealden - - -	
4. Oolite, upper, middle, and lower	
5. Lias - - - -	
6. New red sandstone and muschelkalk	
7. Magnesian limestone and zechstein	
8. Carboniferous - - -	
9. Old red sandstone - -	

* Chap. xxvii.

† For tertiary Mr. De la Beche has used the term "supracretaceous," a name implying that the strata so called are superior in position to the chalk.

10. Ludlow rocks	Upper Silurian	Transition.
11. Wenlock limestone		
12. Caradoc sandstones	Lower Silurian*	
13. Llandeilo flags		
14. Fossiliferous Greywacké	-	

The third group, however, of the above list, or the Wealden formation, although locally of great thickness in the south-east of England, is so partial a deposit that some geologists think it should be merged in the oolite, others in the cretaceous system; to both of which propositions there are objections, as will afterwards appear. The fifth group, or lias, would by many be included in the oolites. The old red sandstone has usually been classed as the lower part of the carboniferous series; but the fossils recently found in it are so distinct from those of the coal, and, on the other hand, from those of the underlying Ludlow rocks, that it seems fairly entitled, on these grounds as well as from its great thickness in parts of England and Scotland to stand as a separate section.

Among other objections to the above classification it may be said that the tertiary group, comprehending all the deposits from the Eocene strata to the Newer Pliocene inclusive, is of greater importance than many of the other divisions. It may also be suggested that the oolitic formation might admit of three subdivisions, each as much entitled to rank as an independent formation as the lias. The following would, perhaps, be a nearer approximation to an arrangement in which the leading divisions would be of equivalent value, as estimated by the successive changes in organic life implied by the imbedded fossil remains and by the geographical extent and thickness of the strata: —

* For explanation of the term "Silurian," see p. 306.

1. Pliocene.
2. Miocene.
3. Eocene.
4. Maestricht and Chalk.
5. Green sand.
6. Wealden.
7. Upper Oolite.
8. Middle Oolite.
9. Lower Oolite.
10. Lias.
11. New red sandstone and Muschelkalk.
12. Magnesian limestone and Zechstein.
13. Carboniferous formation.
14. Old red sandstone.
15. Ludlow rocks.
16. Wenlock limestone.
17. Caradoc sandstone.
18. Llandeilo flags.
19. Fossiliferous Greywacké.

It is not my intention to enter at present upon a detailed description of the fossiliferous formations older than the tertiary, the elucidation of which might well occupy another volume. The observations about to be offered have chiefly for their object to show how far the rules of interpretation adopted for the tertiary formations are applicable to the phenomena of the older sedimentary rocks.

PRINCIPAL GROUPS. (*Descending Series.*)

1. *Cretaceous Group.—Strata from the Chalk of Maestricht to the Lower Green-sand inclusive.*—F. Table I. p. 309.

The principal subdivisions of this group, as it occurs in England and in several countries of the North of Europe, will be found on consulting Table I. Group F. They are six in number, namely; — 1. the Maestricht beds, — 2. the chalk with flints, — 3. the chalk without flints, — 4. the upper green-sand, — 5. the gault, — 6. the lower green-sand. The newest of these deposits is well seen at St. Peter's Mount, Maestricht, and at Ciply, near Mons, reposing on the upper flinty chalk

of England and France. It is a soft yellowish stone, not very unlike chalk, and "includes siliceous masses, which are much more rare than those of the chalk, of greater bulk, and not composed of black flint, but of chert and calcedony."*

It is characterized by a peculiar assemblage of organic remains, perfectly distinct from those of the tertiary period. M. Deshayes, after a careful comparison, and after making drawings of more than two hundred species of the Maestricht shells, has been unable to identify any one of them with the numerous tertiary fossils in his collection. On the other hand, there are several shells which are decidedly common to the calcareous beds of Maestricht and the white chalk; as, for example, the twelve following species, of which the names have been communicated to me by M. Deshayes:—Catillus (Inoceramus) Cuvieri? (specimens imperfect), Plagiostoma spinosa, P. Hoperi, Pecten fragilissimus, Ostrea vesicularis, O. carinata, Crania Parisiensis, Terebratula octoplicata, T. carnea, T. pumilus (magus, *Sow.*), T. Defrancii, Belemnites mucronatus.

But the fossils of the Maestricht beds extend not merely into the white chalk of the French geologists, but into their "chloritic, or green-sand," which corresponds with the upper green-sand of the English geologists. The following five species of shells have been recognized by M. Deshayes as common to the Maestricht beds and the upper green-sand of France:—Plagiostoma spinosa, Ostrea vesicularis, O. carinata, Belemnites mucronatus, and Baculites Faujasii.

Count Munster has shown me, among the fossils

* Fitton, Proceedings of Geol. Soc., 1830.

which he himself collected at Maëstricht, three species of ammonite, among which is *A. Rhotomagensis* (Defrance); also a species of Hamite, and Hippurites Desmoulinsi (Golf). The same eminent naturalist has discovered no less than forty species of microscopic cephalopoda in the same formation, all of species distinct from any known either as recent or tertiary, and many of new genera. There is also an ammonite, obtained from the Maestricht limestone by Dr. Fitton, now in the museum of the Geological Society of London. The occurrence of these ammonites and species of kindred genera, such as the Baculite and Hamite, as also the Belemnite, is important, as showing that the subdivision (No. 1.) now under consideration should be classed as the newest member of the secondary series, rather than as a link between it and the tertiary. No shell hitherto found, even in the oldest or Eocene tertiary formations, minutely as these have been investigated, approaches more nearly in its structure to the ammonite than the Nautilus; nor is there any one which bears a considerable resemblance to the Belemnite, the one which comes nearest to it being the Beloptera of the Paris basin. We can scarcely expect, therefore, to discover in existing tropical seas any living representatives of those curious cephalopoda, the ammonites and belemnites, which evidently swarmed in the ocean when the cretaceous and many preceding groups of strata were formed. They even seem to have become entirely extinct, at least in European latitudes, before the commencement of the Eocene period.

The rock commonly known as chalk preserves its peculiar mineral character throughout a considerable area in Europe, but it is rarely of such thickness as in

many parts of the south-east of England, where horizontally stratified masses about one thousand feet thick are composed of it. Its upper member in this country is usually called the "Chalk with flints;" but above this mass there is in some places another deposit of white chalk without flints, which was found, by boring at Diss, in Norfolk, to attain a thickness of 100 feet.* This chalk stretches over a large part of our island, and recurs in the north of Ireland, is found in Denmark and the south of Sweden, and even in Poland and part of Russia. In France it surrounds and underlies the strata of the Paris basin before described (see Map, Fig. 132. p. 222.), from whence it stretches northward into Belgium and the north of Germany, and southward to the basin of the Gironde. I have seen it, still retaining nearly all the same characters, between Bordeaux and Dax; but it changes its aspect greatly on the flanks of the Pyrenees, where its identity can only be established by the similarity of its fossil remains. Even the white chalk, however, varies considerably in its texture, in proportion as we depart from the great central deposit of Europe. In some parts, for example, of the south of France, it becomes oolitic. Here also it contains, together with shells which abound in the north, many other species peculiar to more southern districts, especially of the genera spherulite, hippurite, and nummulite.†

The other divisions of the cretaceous group, Nos. 4, 5, and 6, consist of sands and clays, which have also a wide geographical range. The position of the gault and lower green-sand relatively to the formations of

* Proceedings of Geol. Soc., vol. ii. p. 93.

† Dufrénoy, Bulletin de la Soc. Géol. de France, tom. i. p. 11.

the white and flinty chalk before alluded to, has been elucidated in diagram Fig. 133. p. 237. The fossils of the inferior arenaceous and argillaceous groups are upon the whole very different from those of the chalk before described, but there are many species common to these two great divisions.

The testacea obtained from the entire cretaceous system amount to about one thousand; and if for the sake of classification, we refer every set of strata in Europe which are characterized by these organic remains to one period, we immediately comprehend in it rocks of every variety of mineral composition, yet which always occupy a determinate place in the order of superposition intervening between the tertiary strata and those of the Oolitic period.

In the cretaceous group, thus distinguished, we behold in the Pyrenees and in Spain compact and crystalline marbles, masses of gypsum and salt, puddingstones, red sandstone, thin shales and grits, containing impressions of marine plants, and other rocks, to which there is nothing analogous in formations of the same age in northern Europe.

It appears, by the researches of MM. Boblaye and Virlet, that in the Morea a great cretaceous system occurs, composed of compact and lithographic limestones of great thickness; also of granular limestones, with jasper; and in some districts, as in Messenia, a puddingstone with a siliceous cement more than 1600 feet in thickness.*

It is evident, observe these geologists, from the great range of the hippurite and nummulite limestone, a rock belonging to the same era, that the South of Europe was

* Bull. de la Soc. Géol. de France, tom. iii. p. 149.

occupied at the period of the cretaceous depositions by an immense sea, which extended from the Atlantic Ocean into Asia, and comprehended the South of France, together with Spain, Sicily, part of Italy, and the Austrian Alps, Dalmatia, Albania, a portion of Syria, the isles of the Ægean, coasts of Thrace, and the Troad.

The plants found in the chalk of England and France are chiefly marine. Some wood has been occasionally met with, both in the chalky rock and its flints, having the appearance of being drifted, and commonly marked with the perforations of boring shells, such as the Teredo and Fistulana.* In Sweden, M. Nilsson has found beds of lignite associated with our common chalk fossils†; so that we may conclude that forests grew on the lands of this period, wherever these may have been placed; but as yet their site is mere matter of conjecture.

The testacea, zoophytes, crustacea, and fishes, are marine, and no bones of mammiferous quadrupeds or birds have yet been discovered; but in the Maestricht beds large turtles have been found, and a gigantic reptile, the Mosasaurus, or fossil Monitor, of Maestricht, some of the vertebræ of which appear also in the English chalk.‡ The osteological characters of this oviparous quadruped prove it to have been intermediate between the living Monitors and Iguanas; and, from the size of the head, vertebræ, and other bones, it is supposed to have been twenty-four feet in length.

In reviewing the facts above enumerated, I may first

* Mantell, Geol. of S. E. of England, p. 96.

† Petrificata Suecana, 1827.

‡ See Mantell's Geol. of S. E. of England.

call attention to the important circumstance that no species of fossil shell has yet been found common to the secondary and tertiary formations; a fact stated on the authority of M. Deshayes, who assures me that he has seen no *tertiary* shells in the Gosau beds, supposed by some geologists to be intermediate between the secondary and tertiary formations. On the other hand, some of the most characteristic species of Gosau occur in the green-sand beneath the chalk, at Ciply, south of Mons, in Belgium, and at some neighbouring places which I have visited. Count Munster also informs me, that the zoophytes which he possesses from the Gosau beds differ specifically from any which he knows as tertiary. I mention this in the hope that the identifications which have been made of Gosau and tertiary species may be re-examined with scrupulous care, for, if confirmed, they would be of the greatest theoretical interest.

This marked discordance in the organic remains of the two series is not confined to the testacea, but extends, so far as a careful comparison has yet been instituted, to all the other departments of the animal kingdom, and to the fossil plants. Dr. Agassiz, whose great work on fossil fish is now in progress of publication, has discovered no species of fish common to the secondary and tertiary rocks.

There appears, then, to be a greater chasm between the organic remains of the Eocene and Maestricht beds, than between the Eocene and Recent strata; for there are some living shells in the Eocene formations, while there are no Eocene fossils in the newest secondary group. It is not improbable that a longer interval of time may be indicated by this greater dissimilarity in fossil remains. In the 3d and 4th

chapters I endeavoured to point out that we have no right to expect, even when we have investigated a greater extent of the earth's surface, that we shall be able to bring to light an unbroken chronological series of monuments from the remotest eras to the present; but, as we have already discovered a long succession of deposits of different ages, between the tertiary groups first known and the *recent* formations, so we may, perhaps, hereafter detect an equal, or even greater series, intermediate between the Maestricht and Eocene strata.

The different subdivisions of the cretaceous group (No. 1.), extending from the chalk of Maestricht to the lower green-sand inclusive, may, perhaps, relate to a lapse of ages as immense as the united tertiary periods, of which the eventful history has been sketched in this work. Such a conjecture, at least, seems warranted, if we can form any estimate of the quantity of time, by comparing the amount of vicissitude in animal life which has occurred during its lapse.

2. *The Wealden, or the Strata from the Weald Clay to the Purbeck Limestone inclusive.*—G, Table I. p. 309.

It will be seen by the Table I. p. 309., that in the South of England this group may be divided into three formations — the Weald clay, the Hastings sands, and the Purbeck beds, which are all characterized by the remains of fresh-water animals; whereas the cretaceous strata which are superimposed upon the Wealden, in the south-east of England, contain fossils of marine species.*

* The term Wealden was suggested by Mr. Martin, and will be found of great convenience.

The position of these beds has been indicated in diagram Fig. 133. page 237., and the map (Plate XV.) will show the superficial area occupied by them in Kent, Sussex, Surrey, and Hampshire. It must not be supposed, however, that they terminate at the points where they happen to be covered by the cretaceous system. The same group has been ascertained to extend from west to east (from Lulworth Cove to the boundary of the Lower Boulonnois), about 200 English miles; and from north-west to south-east (from Whitchurch to Beauvais), 220 miles; the depth or total thickness of the beds, where greatest, being about 2000 feet.* The general appearance of the clays and sands, and of the subordinate beds of limestone, grit, and shale, and of the imbedded shells, recalls so precisely that of many tertiary formations of fresh-water origin, that it is only after having determined the species of organic remains that we recognize a discordance in character as great as might have been anticipated when strata above and below the chalk were compared.

The vegetable remains belong, some of them, to plants which appear to have held an intermediate place between the Equiseta and Palms, as the Clathraria discovered by Mr. Mantell; while others approach to arborescent ferns, the species being very peculiar, and not known in any other deposit, whether of higher or inferior antiquity.†

The shells of the Wealden are almost exclusively fluviatile; and, as is usual in assemblages of fresh-water testacea, a few species only are found, while the individuals are very numerous, sometimes forming the

* Fitton's Geol. of Hastings, p. 58.

† Mantell, Geol. of S. E. of England, chap. xi.

principal component of entire beds of limestone. Shells of the Cypris, also, a fresh-water animal, before mentioned as occurring in the lacustrine deposits of Auvergne, are profusely distributed throughout the Wealden. Of this genus several species have been discovered and figured by Dr. Fitton.*

Some fish, also, of forms resembling known fluviatile genera, have been met with; but the remains of reptiles present the most remarkable feature in this group. Some of these belong to turtles, such as the Trionyx, a genus now occurring in fresh-water in tropical regions: others are referrible to the genus Emys. Of Saurian lizards there are at least five genera; the Crocodile, Plesiosaur, Megalosaur, Iguanodon, and Hylæosaur. The Iguanodon, of which the remains were first discovered by Mr. Mantell, was an herbivorous reptile, and was regarded by Cuvier as more extraordinary than any with which he was acquainted; for the teeth, though bearing a great analogy to the modern Iguanas which now frequent the tropical woods of America and the West Indies, exhibit many striking and important differences. It appears that they have been worn by mastication; whereas the existing herbivorous reptiles clip and gnaw off the vegetable productions on which they feed, but do not chew them. Their teeth, when worn, present an appearance of having been chipped off, and never, like the fossil teeth of the Iguanodon, have a flat ground surface, resembling the grinders of herbivorous mammalia.† From the large bones, found in great numbers near these teeth, and fairly presumed to belong

* See Trans. of Geol. Soc., vol. iv., Second Series, now in the press.

† Mantell, Geol. of S. E. of England, p. 277.

to the same animal, it is computed that the entire length of this reptile could not have been less than seventy feet.

The bones of birds have been found in the Wealden; but in no part has any fragment of the skeleton of a mammiferous quadruped been obtained. With this exception, to which I shall presently revert, the strata of the Wealden present such characters as we might look for in the deposits of the deltas now forming at the mouths of large rivers in tropical climates.

The Wealden, as was before explained, is covered by the marine cretaceous system, and reposes upon another, which is, in like manner, a purely marine deposit; namely, the uppermost member of the Oolite, or group H, Table I. p. 310.

This intercalation of a great fresh-water formation between two others of marine origin is a remarkable fact, and attests, in a striking manner, the great extent of former revolutions in the position of sea and land. In those sections where the junction of the fresh-water and cretaceous system is seen, the beds of the lower green-sand have been observed to repose conformably upon those of the subjacent Weald clay. There is no indication of disturbance: "To all appearance the change from the deposition of the fresh-water remains to that of the marine shells may have been effected simply by a tranquil submersion of the land to a greater depth beneath the surface of the waters."*

At the point of contact of the *inferior* division of the Wealden or "Purbeck beds," with the more ancient marine system, a very curious phenomenon is observed: the fresh-water calcareous strata repose, both in Portland and Purbeck, upon the oolitic limestone, called

* Dr. Fitton, Geol. of Hastings, p. 28.

the Portland stone, which abounds with Ammonites, Trigoniæ, and other marine shells. Between the two formations there intervenes "a layer, about a foot in thickness, of what appears to have been an ancient vegetable soil; it is of a dark brown colour, contains a large proportion of earthy lignite, and, like the modern soil on the surface of the island, many water-worn stones. This layer is called the "dirt-bed" by the quarrymen; and in, and upon it, are a great number of silicified trunks of coniferous trees, and plants allied to the recent *cycas* and *zamia*. Many of the stems of the trees, as well as the plants, are still erect, as if petrified while growing undisturbed in their native forest; the trees having their roots in the soil, and their trunks extending into the superincumbent strata of limestone."*

Traces of this vegetable earth, occupying the same relative situation, have been observed by Dr. Fitton in the cliffs of the Boulonnois, on the opposite coast of France.† Dr. Buckland and Mr. De la Beche have also ascertained that many of the stumps of trees remain erect, with their roots attached to the black soil on which they grew, their upper part being imbedded in the limestone; from which they infer, "that the surface of the subjacent Portland stone was for some time dry land, and covered by a forest, and probably in a climate such as to admit the growth of the modern Zamia and Cycas." ‡

* Mantell, Geol. of S. E. of England, p. 336.—See also papers by Mr. Webster, Dr. Buckland, and Mr. De la Beche, Geol. Trans., Second Series, vol. ii. Mr. Webster was, I believe, the first to notice the erect position of the stems.

† Geol. of Hastings. Geol. Proceedings, vol. i. p. 9.

‡ Proceedings of Geol. Soc., April, 1830.

It seems a legitimate deduction from the data above explained, that the marine formations of an antecedent period (that of the oolite) had become land throughout a portion of the space now occupied by the South of England and the opposite coast of France; and that this land then sank down, with its forests, and became submerged beneath the waters of a great river, just as the region around Sindree, in Cutch, subsided in 1819, and was permanently laid under water, being at one time occupied by the fresh water of the Indus.* The country may then have continued to subside, until a thickness of two thousand feet of fluviatile sediment had been gradually accumulated; and this deposit, or delta, by a continuation of the same depressing operations, may, in its turn, have become buried deep beneath the sea in which the chalk was formed.

I shall not enter farther into these speculations at present, but proceed to inquire how far the Wealden is connected by its fossil remains with the overlying or subjacent formations. First, we may ask whether there are any species of fossil animals or plants common to the fresh-water group and to the oolitic system. I am aware of one example only, the Megalosaurus Bucklandi; for the teeth and bones of this great saurian occur in the Stonesfield oolite and the Hastings sands, the remains in both cases having been referred by Cuvier to the same species. There are also some *generic* forms both of reptiles and fish common to the Oolite and Wealden, and not yet discovered in the Chalk. Vertebræ, for example, of the Plesiosaurus are not confined to the oolite and lias, but have been also found in the Wealden; and the Lepidotus, a genus of fish

* See Vol. II. p. 237., and Vol. III. p. 273., and Plate V.

very characteristic of the Wealden, is unknown in the cretaceous group, while it is abundant in the oolitic series. On the other hand, the same Iguanodon Mantelli, which is so conspicuous a fossil in the Wealden, has recently been discovered near Maidstone in the overlying Kentish rag, a marine limestone of the lower green-sand. From this fact we may infer that some of the saurians which inhabited the country of that great river, which by its sediment produced the Wealden strata, continued to live when part of the country had become submerged beneath the sea. Thus, in our own times, we may suppose the bones of large alligators to be frequently entombed in recent fresh-water strata in the delta of the Ganges. But if part of that delta should sink down so as to be covered by the sea, marine formations might begin to accumulate in the same space where fresh-water beds had previously been formed; and yet the Ganges might still pour down its turbid waters in the same direction and carry the carcasses of the same species of alligator to the sea, in which case their bones might be included in marine as well as in subjacent fresh-water strata.

Near Beauvais, in France, there is a small valley of elevation and denudation, closely resembling in structure that of the Weald, and called the country of Bray, where the green-sand crops out from beneath the chalk, and where strata, for the most part like those of the Wealden, appear beneath the green-sand. One member of the series, a fine whitish sand, contains impressions of ferns, considered by M. Adolphe Brongniart as identical with Lonchopteris Mantelli, a plant found frequently in the Wealden. I examined part of the valley of Bray in company with M. Graves, in 1833, and I observed that the sand last mentioned, with its

vegetable remains, was intercalated between two sets of marine strata, containing trigoniæ, and referred, by French geologists, to the lower green-sand. In the same country of Bray, and associated with the same formation, is a limestone resembling the Purbeck marble, and containing a Paludina which seems specifically identical with that of Purbeck.

There are some few species, therefore, of the Wealden common on the one hand to the overlying cretaceous group, and on the other to the subjacent oolite; but the connection hitherto established is so slight that the era of the fresh-water deposit may have been separated by a wide interval of time from the periods when the animals either of the oolitic or cretaceous periods predominated.

3. *Oolite, or Jura Limestone Formation.*—H, Table I. p. 310.

The different subdivisions which have been made for the classification of the rocks of this group in England are enumerated in Table I. p. 310. It consists of limestone, clay, marl, and sand; which, considered in the aggregate, retain the same lithological characters throughout a considerable part of England, France, and Germany. It is not to be expected that we should be able to follow the different members of the English series throughout Europe, as they vary greatly, both in mineral and organic characters, in their course throughout different parts of our own island; but, as the fossils of the higher, middle, and lower parts of the series are not the same, it may be possible, by their aid, to establish subordinate groups of great utility.

The coral rag of England, and analogous zoophytic

limestones of the oolitic period in different parts of Europe, bear a resemblance to the coralline formations now in progress in the seas of warmer latitudes.

In the lithographic limestone of Solenhofen, belonging to one of the upper members of the series, a great variety of organic remains is found. Among these I have seen in the museum of Count Munster no less than seven *species* of flying lizards, or Pterodactyls, six saurians, three tortoises, sixty species of fish, forty-six of crustacea, and twenty-six of insects. The number of testacea is comparatively small, as also of plants, which are all marine. Count Munster had determined 237 species from the Solenhofen slate when I saw his collection in 1833. The extreme fineness of the sediment has, in this instance, allowed impressions of some of the most delicate and soft parts of various animals to be preserved; as of the belemnite and several insects.

In the Stonesfield slate (see Table), the remains of many reptiles have been found associated with marine shells, and the jaws of at least two species of small mammiferous quadrupeds of a genus allied to the Didelphys, or Opossum.* It is very remarkable, that these fossils afford the only exception yet known to the apparent absence of all terrestrial mammalia from the islands and continents which existed anteriorly to to the Eocene period.

4. *Lias.* I, Table I. p. 311.

The English provincial name of Lias has been very generally adopted for a formation of argillaceous limestone, marl, and clay, usually found in conformable stratification to the rocks of the oolite group before de-

* See Fig. 2 and 3. Vol. I. pp. 232, 233.

scribed. Some geologists regard the lias as the lowest member of the oolite group, several species of organic remains being common to it and to the inferior oolite. If we draw a line between these formations, the separation will be somewhat arbitrary, but may be, nevertheless, convenient; as both the oolite group and the lias will still comprehend a great thickness of strata, characterized, when viewed on the great scale, by assemblages of distinct fossils. The lias retains a uniform mineralogical character throughout a great part of England, France, and Germany; and this circumstance may facilitate the attempt to ascertain the contemporaneous existence of a sufficiently numerous set of fossil plants and animals to enable us to determine the equivalent groups of distant countries.

The remains of reptiles, those of saurians in particular, are very common in the liassic rocks in several parts of England, especially of the genera Ichthyosaurus, Plesiosaurus, and crocodile.

5. *New Red Sandstone group,* K, Tab. I. p. 311. (*including the Muschelkalk of the Germans*).

The deposits which are referrible to the interval which separated the lias from the great coal formation may be divided into two principal groups: first, the New Red Sandstone; secondly, the Magnesian Limestone. The New Red Sandstone of England, accompanied by beds of gypsum and rock salt, is almost entirely destitute of organic remains; but the Muschelkalk of Germany, which is referrible to the same period, and has no precise equivalent among the English strata, contains many fossils of species distinct from those of the lias, or subjacent magnesian limestone.

This calcareous formation (Muschelkalk) is inter-

posed in Bavaria and Wurtemburg, between two others; the overlying "Keuper," or variegated marls, with which it alternates at the junction, and the red mottled sandstone ("bunter sandstein") on which it rests. The plants found by Count Munster in this last, and in the "Keuper," are so similar, as to induce that geologist to regard all the three groups thus connected as belonging to one period; and in confirmation of the same opinion, M. Agassiz finds the same species of fish to be common to the three groups.

6. *Magnesian Limestone (Zechstein of the Germans).* L, Tab. I. p. 312.

This formation consists in England for the most part of a yellowish limestone, in which a small number only of organic remains are preserved, but these are referrible to peculiar and characteristic species.

So also in the zechstein of the Germans, a limestone of this period, and in its accompanying copper slate, the the same or very similar fossils occur. At Mansfeld in Westphalia, for example, fish are found of the extinct genus Palæothryssum, only known in strata of this group. Dr. Agassiz informs me that he has not as yet been able to identify any species from Mansfeld with any one of those found in England, but the genus appears characteristic of the era under consideration.

7. *Carboniferous Group, comprising the Coal-measures, and the Mountain Limestone.* M, Tab. I. p. 312.

The rocks of this group consists of limestone, shale, sandstone, and conglomerate; interstratified with which are large beds of coal, a substance now universally admitted to be of vegetable origin. Several hundred species of plants have been found in the shales and

sandstones associated with the coal, and all are, with few exceptions, of species differing widely from those which mark the vegetation of other eras. Some remarks have been offered in the first book*, respecting the known geographical extent of the coal formation and the tropical character of its flora, and of the shells and corals of the carboniferous or mountain limestone.† I there adduced arguments for inferring that the lands in northern latitudes consisted, for the most part, at that remote era, of small islands; and mentioned the absence of large saurian remains, the insular character of the flora, and the deposition of the strata, as favouring that opinion.

But although the higher latitudes of the northern hemisphere probably formed at that time a great archipelago, they must have contained some islands of sufficient magnitude to allow of the existence of rivers, lakes, and marshes, where fresh-water strata were accumulated. A fresh-water limestone has been discovered and described by Dr. Hibbert at Burdiehouse near Edinburgh, as lying beneath marine strata of the carboniferous group. Instead of containing fossil corallines or encrinites, like the mountain-limestone, the formation in question contains land plants in great abundance, and minute entomostraca allied to the genus Cypris‡ and several fish.

Mr. Hutton states that, in part of the coal-field of Northumberland and Durham, fossil shells of a species of Unio occur in considerable abundance in a shale containing plants of the carboniferous period, and overlying a bed of coal. The coal has been worked out from

* Vol. I. pp. 196. to 198. † Vol. I. p. 153.

‡ See above, p. 163.

beneath the shells, which have been already proved to extend over an area five thousand feet square. The shelly stratum is about eighteen inches thick; and the animals have evidently died at various ages, the shells being of every size. This accumulation of bivalves of one species, and of this form, seems clearly to indicate the continuance on the spot of a body of fresh-water, such as might be found in the estuary of a river.*

In the Shropshire coal-field near Bridgnorth, and in other places, Mr. Murchison has shown that the upper coal-measures contain a subordinate bed of limestone, which may be termed lacustrine, as a small species of Planorbis is plentifully imbedded in it.†

8. *Old Red Sandstone.* N, Table I. p. 313.

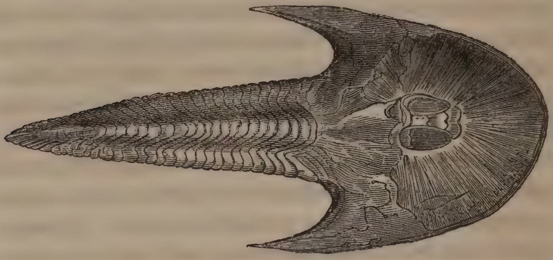
Beneath the coal-series in the northern part of Fifeshire in Scotland, and the southern half of Forfarshire, a formation occurs of great thickness, composed of red marl, conglomerate, red and white sandstone, and shales of various colours, for the most part devoid of organic remains. In some of the shales, however, impressions of plants apparently marine, have been met with, and in the flaggy sandstones containing a slight admixture of carbonate of lime, the scales and other remains of fish are not unfrequent. They belong to a genus named by Dr. Agassiz "Cephalaspis," or "buckler-headed," from the extraordinary shield which covers the head. (See Fig. 153.) This peculiar form of fish, which is quite unknown in the coal-strata, seems characteristic of the old red sandstone generally; for it is found in Herefordshire and other counties of England and Wales, where the old red-sandstone is

* Fossil Flora, by Lindley and Hutton, No. 10.

† Proceedings of Geol. Soc., No. 38. p. 119.

largely developed. All the animal and vegetable remains hitherto discovered in this series are dis-

Fig. 153.



Cephalaspis Lyellii, Agass. Length $6\frac{3}{4}$ inches.

This figure is from a specimen now in my collection, which I procured at Glammis in Forfarshire. An account of it will appear in the work on Fossil Fish, by Dr. Agassiz, who named the species after me.

tinct from those of the overlying coal, or subjacent transition strata.

9. *Transition, or Greywacké Formations.* O. & P. Table I. p. 313.

Continental and English authors have not always been agreed where the line of separation should be drawn between the secondary and transition formations. Some of them, for example, have included the carboniferous group in the secondary, others in the transition system. But in England the old red sandstone has been generally considered as the lowest member of the secondary series.

The name of transition was first given by Werner to certain sedimentary deposits consisting, in the Hartz and many parts of Germany, of arenaceous and brecciated rocks which alternate with argillaceous schist, and are sometimes associated with corallines and

shelly limestones. These were supposed to have been the earliest formed strata when the ocean first became habitable by aquatic beings. Although the principal members of this group, where it is largely developed, are evidently of mechanical origin, they often alternate with beds of quartz and argillaceous schist, not distinguishable mineralogically from crystalline rocks classed by Werner as primitive. Hence, as was before stated, the term transition was adopted to express the theory that, at this period, the causes which had given rise to crystalline formations were still in action; while those which produced stratified sedimentary rocks, including organic remains, were also beginning to operate.

The characteristic group called in German "Grauwacke" is an aggregate of small fragments of quartz, Lydian stone, and argillaceous schist, cemented together by argillaceous matter. But far too much importance has been attached to this kind of rock, as if it were peculiar to a certain epoch in the earth's history, whereas it is only an accidental variety of argillaceous sandstone, probably in some cases altered by heat. There are parts of England and Sweden where fossiliferous strata more ancient than the old red sandstone are largely developed, and yet where no rocks answering mineralogically to the Greywacké of the Germans are discoverable.

The first great step towards a general table of superposition of the British fossiliferous groups below the old red-sandstone, each distinguished by certain mineral characters and organic remains, has recently been made by Mr. Murchison, and his arrangement has been adopted in Table I. p. 313.

Mr. Murchison has had an opportunity of tracing the succession of deposits in a regular descending

series, from the old red sandstone with which they are in part covered, to the subjacent and unconformable greywacké rocks of South Wales. As far as his examination has hitherto proceeded, all the species of zoophytes and shells differ from those of the carboniferous limestone; while the fossils of his four great subdivisions are distinct from each other.*

He has proposed the term "Silurian," as a general name for this whole system of rocks, derived from "Silures," the principal tribe of Celts or ancient Britons, who occupied part of Wales and the bordering counties of England, where these ancient fossiliferous strata are most distinctly exhibited. The Ludlow rocks and the Wenlock limestone may be classed as the Upper Silurian group, being the deposits which are immediately below the old red-sandstone; while the Caradoc sandstones and Llandeilo flags form the Lower Silurian group. Below all these there are other fossiliferous rocks which, in Wales, are unconformable to the Silurian strata.

Among the fossils of the Silurian formations, zoophytes and crinoidea are the most numerous; and some of the limestones, which are in great part composed of them, agree in their general character with those now in progress in seas where stone-corals are abundant. The Trilobite, a singular crustaceous animal, of which no living species is known, is also characteristic of the rocks of this period; so also the Orthocera, a chambered univalve, of which certain species are found in the carboniferous limestone, but hitherto in no newer deposit. On the other hand, some of the shells belong to recent genera, as the

* Proceedings of Geol. Soc. London, No. 34. 1834.

Terebratula, of which there is a great variety. The only vertebrated remains hitherto found are a few bones of fishes. The shells and zoophytes of these formations have been studied in Germany by Count Munster, Professor Goldfuss, and M. Steininger. In Nassau, M. Stift has endeavoured to classify the different subdivisions of the same series chiefly by reference to their mineralogical characters. M. Hisinger also, who has recently published a geological map of the south of Sweden, as well as Professor Wahlenberg and the late M. Dalman, have described and figured many fossil productions from these strata in Sweden.

With this "Silurian" group I shall conclude; for although other divisions may hereafter be requisite, it does not appear that any antecedent periods can yet be established on the evidence of a distinct assemblage of fossil remains. Traces of organization do undoubtedly occur in rocks of still higher antiquity; but they cannot be referred to a distinct geological period, until we have obtained data for determining the specific characters of a considerable number of fossils.

The annexed table will explain the order of superposition of the successive groups of fossiliferous strata hitherto established in Europe; it should be remembered, however, that it is in a small part of western Europe only that almost all this series of monuments has been discovered.

Table I.

TABLE I.

Showing the Order of Superposition, or Chronological Succession, of the principal European Groups of Sedimentary and Fossiliferous Strata.

This Table is also referred to in the Glossary.

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.		Some of the Localities where the Formation occurs.
I. Recent Period.		The deposits of this period are for the most part concealed under existing lakes and seas.		
I. Recent Period.	A.	Consolidated sandy and gravelly beds (a), travertin limestones (b), calcareous sandstones with broken shells (c), coral limestone, consisting of corals, shells, &c. (d), compact limestone (e).		a. Delta of the Rhone. b. Tivoli, and other parts of Italy. c. Shore of island of Guadaloupe. d. Coral reefs in Pacific, &c. e. Bermudas.
II. Tertiary Period.	B. Newer Pliocene.	MARINE. Limestone, sands, clays, sandstones, conglomerates, marls with gypsum; containing *marine* fossils (a).	FRESH-WATER. Sands, clays, sandstones, lignites, &c.; containing *land* and *fresh-water* fossils (b).	a. Sicily, Ischia. b. Colle in Tuscany.
II. Tertiary Period.	C. Older Pliocene.	*Subapennine marl, Subapennine yellow sand, English "crag,"* and other deposits, as in B., containing *marine* fossils (a).	Similar deposits to B.; containing *land* and *fresh-water* fossils (b).	a. Subapennine formations, Perpignan, Nice, Norfolk, and Suffolk. b. Near Sienna, &c.
II. Tertiary Period.	D. Miocene.	*Faluns of the Loire*, and other deposits varying in mineral composition, as those in B. and C., containing *marine* fossils (a).	Similar deposits to B. and C.; containing *land* and *fresh-water* fossils (b).	a. Touraine, Bordeaux, Valley of Bormida, Superga near Turin, Basin of Vienna. b. Saucats, twelve miles south of Bordeaux.

TABLE I. — *continued.*

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.		Some of the Localities where the Formation occurs.
II. TERTIARY PERIOD— *continued.*	E. Eocene.	*Calcaire grossier* (*a*), *London clay*, sands, sandstones, &c., with *marine* fossils (*b*).	*Calcaire siliceux* — sandstones and conglomerates, red marl, green and white marls, limestone, gypseous marls,—with *land* and *fresh-water* fossils (*c*).	*a.* Paris basin. *b.* Paris, London, and Hampshire basins, Isle of Wight. *c.* Paris basin, Isle of Wight, Auvergne, Velay, Cantal.
III. SECONDARY PERIOD.	F. Cretaceous Group.	1. *Maestricht Beds.* — Soft yellowish-white limestone with siliceous masses, resembling chalk (marine).		St. Peter's Mount, Maestricht. Ciply, near Mons.
		2. *Chalk with flints* (marine).		North and South Downs, and parts of the intervening Weald of Kent, Surrey, and Sussex. Yorkshire; North of Ireland. Beauvais, France.
		3. Chalk without flints (marine).		
		4. *Upper green sand* (marine).— Marly stone, and sand with green particles; layers of calcareous sandstone.		
		5. *Gault* (marine). — Blue clay, with numerous fossils, passing into calcareous marl in the lower parts.		
		6. *Lower green sand* (marine). — Grey, yellowish, and greenish sands, ferruginous sands and sandstones, clays, cherts, and siliceous limestones.		
	G. Wealden Group.	1. *Weald Clay* (fresh-water). — Clay, for the most part without intermixture of calcareous matter, sometimes including thin beds of sand and shelly limestone.		1, 2. Extensively deve-

TABLE I.—*continued.*

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. SECONDARY PERIOD — *continued.*	G Wealden Group, *continued.*	2. *Hastings sands* (freshwater). — Grey, yellow, and reddish-brown sands, sandstones, clays, calcareous grits passing into limestone.	loped in the central parts of Kent, Surrey, and Sussex.
		3. *Purbeck beds* (freshwater). — Various kinds of limestones and marls.	3. Isle of Purbeck, in Dorsetshire.
	H. Oolite, or Jura Limestone Group.	1. *Portland beds* (marine). — Coarse shelly limestone, fine-grained white limestone, compact limestone — all more or less of an oolitic structure; beds of cherts.	Isle of Portland, Tisbury in Wiltshire, Aylesbury.
		2. *Kimmeridge clay* (marine). — Blue and greyish-yellow slaty clay, containing gypsum, bituminous slate (Kimmeridge coal).	Near Kimmeridge on coast of Dorsetshire — Sunning Well, near Oxford.
		3. *Coral rag* (marine). — Calcareous shelly freestones, largely oolitic; coarse limestone, full of corals; yellow sands; calcareous siliceous grits.	Headington, near Oxford — Farringdon, in Berkshire — Calne and Steeple Ashton, in Wiltshire — Somersetshire.
		4. *Oxford clay* (marine). — Dark blue tenacious clay, with septaria, bituminous shale, sandy limestone (Kelloway rock), iron pyrites, gypsum.	New Malton, in Yorkshire — Lincolnshire — Cambridgeshire — Huntingdonshire, and midland counties — abundantly near Oxford — Somersetshire — Dorsetshire.
		5. *Cornbrash* (marine). — Grey or bluish rubbly limestone, separated by layers of clay.	Malmsbury, Atford, Wraxall, Chippenham.

TABLE I.—*continued.*

Periods and Groups.	Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. Secondary Period — *continued.* H. Oolite, or Jura Limestone Group — *continued.*	6. *Forest marble* (marine).— Calcareo-siliceous sand and gritstone; thin fissile beds of limestone, with clay partings; coarse shelly limestone.	Whichwood Forest, Oxfordshire — Frome, south-east of Bath.
	7. *Great oolite* (marine). — White and yellow oolitic calcareous freestone, coarse shelly limestone, layers of clay. Oolitic limestone, with remains of land animals, birds, amphibia, plants, sea-shells (*a*).	Bath—Burford in Oxfordshire—Bradford in Wiltshire. *a*. Stonesfield, near Woodstock, Oxfordshire.
	8. *Fuller's earth clay* (marine). — Clay containing in some places fuller's earth.	Near Bath.
	9. *Inferior oolite* (marine).— Soft freestone, sand with calcareous concretions.	Cotteswold Hills — Dundry Hill, near Bristol.
	Limestones of various qualities, clays, sands, and sandstone, containing the same fossils as those occurring in the series of the oolitic group of England, constitute the main body of the Jura chain of mountains, and cover vast tracts of country in Germany.	
I. Lias Group.	*Lias* (marine). — Shale and sandy marlstone. Blue, white, and yellow earthy limestone, usually in thin beds, interstratified with clay, often slaty and bituminous.	Lyme Regis in Dorsetshire, and in many parts of Somersetshire — Yorkshire — in Sutherlandshire, the Hebrides, and North of Ireland. In France, as at Metz, and to a considerable extent in Germany, as in the Swabian Jura.
K.	1. *Keuper, or variegated marls.* — Red, grey, green, blue, and white marls, sandstones, conglomerates, and shells, containing gypsum and rock-salt.	Neighbourhood of Vosges mountains, and many parts of Wurtemberg and Westphalia, Nuremberg.

TABLE I. — *continued.*

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
III. Secondary Period — *continued.*	K. New Red Sandstone Group — *continued.*	2. *Muschelkalk* (marine). — Grey, blue, and blackish limestone, with alternating clay and marl, and with siliceous layers, and nodules.	Extensively developed in Germany and France. Hitherto no beds in England have been identified with the formation.
		3. *Variegated (Bunter) sandstone.* — Red, white, blue, and green siliceo-argillaceous sandstone, often micaceous, and containing gypsum and rock-salt.	Nottinghamshire — Yorkshire. Stuttgardt.
	L. Magnesian Limestone Group.	1. *Magnesian limestone* (*a*) (marine). — Marl-slate, shelly limestone, variegated marls, yellow magnesian limestone. *Zechstein of Germany* (*b*)— limestone — marl-slate, containing copper ore, and impressions of fish.	*a.* Nottinghamshire, Derbyshire, Yorkshire, Durham, Northumberland. *b.* Mansfeld in Thuringia.
		2. *Red conglomerate.*—Sandstones, conglomerates, sands, and marls.	Neighbourhood of Exeter.
	M. & N. Carboniferous Group.	1. *Coal measures* (fresh-water and marine). — Sandstones, grits, conglomerates, clays, with ironstone, shales, and limestone, interstratified with beds of coal.	Northumberland, Durham, Yorkshire, Lancashire, Staffordshire, Somersetshire, South Wales, Valleys of the Forth and Clyde. District of Liege, Westphalia, Silesia, Bohemia, &c.
		2. *Mountain limestone* (marine). — Grey, compact, and crystalline limestone, abounding in lead ore in North of England, and alternating with coal measures in Scotland.	Mendip Hills, Derbyshire, Yorkshire, Durham, Northumberland, Lanarkshire, Linlithgowshire, many parts of Ireland. North-west of Germany, Belgium, North of France.

TABLE I. — *continued.*

Periods and Groups.		Names of the principal Members and Mineral Nature of the Formation, in Countries where it has been most studied.	Some of the Localities where the Formation occurs.
	N.	1. *Old red sandstone.*—Coarse and fine siliceous sandstones and conglomerates of various colours, red predominating.	Extensively developed in Shropshire and Herefordshire, Brecknockshire, Dumfries-shire, Forfarshire. Silesia, Bohemia.
IV. Transition Period. Silurian Group.	O.	1. *Ludlow rocks* (marine).— Argillaceous limestone, sandy shale.	Ludlow Castle, Shropshire; Aymestry and Woolhope, Herefordshire.
		2. *Wenlock limestone* (marine). — Coralline limestone and argillaceous shale, with nodules of earthy limestone.	Wenlock Edge, Shropshire, Dudley, Worcestershire.
		Caradoc sandstones (marine). — Shelly limestone and micaceous sandstone, quartzose grits and sandy limestones.	Horderly, Shropshire; and May Hill, Gloucestershire. East flank of Wrekin and Caer Caradoc, Shropshire.
		4. *Llandeilo flags* (marine). — Calcareous flags, sandstone and schist.	Llandrindod, near Builth, Radnorshire. Llandeilo, Caermarthenshire.
	P.	Fossiliferous greywacké, and rocks older than the Silurian, but in which no distinct assemblage of organic remains have as yet been specifically determined.	

CHAPTER XXIV.

ANALOGY OF THE OLDER FOSSILIFEROUS TO THE TERTIARY STRATA.

That land as well as sea existed at each successive period — Some former continents placed where it is now sea—Secondary fresh-water deposits, why rare (p. 320.)—Persistency of mineral composition, why apparently greatest in older rocks—Supposed universality of red marl formations — Secondary rocks, why more consolidated — why more fractured and disturbed (p. 325.) — Secondary volcanic rocks of many different ages.

In the last chapter I stated that no detailed account of the older fossiliferous formations would be attempted in this work, and that I should confine myself almost exclusively to the inquiry how far the rules of interpretation previously adopted for the tertiary groups might be applied to the phenomena of more ancient strata. To this point the following remarks are chiefly directed:—

Position of former continents. — The existence of land as well as sea, at every geological period, is attested by the remains of terrestrial plants imbedded in the deposits of all ages, even the most remote. We find fluviatile shells not unfrequently in the secondary strata, and here and there some fresh-water formations; but the latter are less common than in the tertiary series. For this fact the reader's mind has been prepared, by the views advanced in the third

er respecting the different circumstances under which the secondary and tertiary strata appear to have originated. The secondary, it was suggested, may have been accumulated in an ocean like the Pacific, where coralline and shelly limestones are forming; or in a basin like the bed of the western Atlantic, which may have received, for ages, the turbid waters of great rivers, such as the Amazon and Orinoco, each draining a considerable extent of continent. The *tertiary* deposits, on the other hand, very probably accumulated during the growth of a continent, by successive emergence of new lands, and the uniting together of islands. During such changes, inland seas and lakes would be caused, and their basins afterwards filled up with sediment, and then raised above the level of the waters.

That the greater part of the space now occupied by the European continent was sea when some of the secondary rocks were produced, must be inferred from the wide areas over which several of the marine groups are diffused; but we need not suppose that the quantity of land was less in those remote ages, but merely that its position was very different.

It has been shown that, immediately below the chalk and green-sand, a fluviatile formation, called the Wealden, occurs, which has been ascertained to extend from west to east, about 200 English miles, and from north-west to south-east, about 220 miles, the depth or total thickness of the beds, where greatest, being about 2000 feet.* These phenomena clearly indicate that there was a constant supply in that region, for a long period, of a considerable body of fresh water, such as might be supposed to have drained a continent, or a

* Fitton's Geology of Hastings, p. 58.

large island, containing within it a lofty chain of mountains. Dr. Fitton, in speaking of these appearances, recalls to our recollection that the delta of the newly discovered Quorra, or Niger, in Africa, stretches into the interior for more than 170 miles, and occupies, it is supposed, a space of more than 300 miles along the coast; thus forming a surface of more than 25,000 square miles, or equal to about one half of England.*

If asked where the continent was placed from the ruins of which the Wealden strata were derived, we might be almost tempted to speculate on the former existence of the Atlantis of Plato as true in geology, although fabulous as an historical event. We know that the present European lands have come into existence almost entirely since the deposition of the chalk (see map, Plate II.); and the same period may have sufficed for the disappearance of a continent of equal magnitude, situated farther to the west.

But among the numerous fossils of the ancient delta of the Wealden no remains of mammalia have been detected; whereas we should naturally expect, on examining the deposits recently formed at the mouths of the Quorra, Indus, or Ganges, to find, not only the bones of birds and of amphibious and land reptiles, but also those of the hippopotamus, and other mammalia which frequent the banks of rivers. Mr. Mantell seems to have demonstrated †, that the remains of the animals and plants found fossil in the Wealden have, with the exception of the testacea and other aquatic tribes, been transported for a considerable distance, the stems of the plants being, for the most part, torn

* Fitton, Geol. of Hastings, p. 58., who cites Lander's Travels.

† Geol. of S. E. of England, p. 329.

and intermingled with pebbles of quartz, slate, and jasper; while the bones of lizards, turtles, and fish, are detached from the skeleton, and more or less broken and rolled. But, admitting that these fossils were drifted for many a league, we might fairly expect that, at least, some fragments of mammiferous bones would have reached the delta.

It is certainly a startling proposition to suppose, that a continent covered with vegetation, which had its forests of palms and tree-ferns, and its plants allied to the Dracæna and Cycas, which was inhabited by large saurians, and by birds, was, nevertheless, entirely devoid of land quadrupeds. If the proofs were confined to the Wealden, we might hesitate to lay much stress on mere negative evidence, since extensive deposits of the Eocene period, such as the London clay, have as yet yielded no mammiferous fossils. But when we find the same general absence of mammalia in strata of the Oolitic and Liassic eras, we can hardly refuse to admit that the highest order of quadrupeds was very feebly represented in those ages, when the small Didelphys of Stonesfield was entombed. Some of the bones, indeed, collected by Dr. Buckland from the oolitic series have been pronounced by Cuvier to be cetaceous; but that naturalist has himself remarked how closely the vertebræ of the larger reptiles resemble those of certain dolphins; so that it is highly desirable that the fossils alluded to should be re-examined with great care.*

So far, then, as our present inquiries enable us to judge, there are strong indications that, during the

* Mantell, Geol. of England, p. 282.; and see above, Vol. I. p. 227.

periods of the Wealden, the Oolite, and Lias, there was a large development of the reptilia, at the expense, as it were, both of the cetaceous and terrestrial mammalia.

It may be well, then, to inquire whether this difference in the state of animal life in the northern hemisphere, at these remote periods, is irreconcileable with the notion of the constancy and uniformity of the laws which govern the changes of the organic world. Would the almost entire suppression of one important class of vertebrated animals, and the larger development of another, if fully established on farther investigation, imply that there are no fixed rules according to which the form, structure, and attributes of animals are accommodated to the endless vicissitudes of the earth's surface? Or are the rules, if any, made to endure for a time only, new ones being substituted at each successive period? Or, is it conceivable that the distinct zoological characters of certain secondary groups, as compared to others of the tertiary epoch, may depend on laws as uniform as those which, from one century to another, appear to determine the growth of certain tribes of plants and animals in the arctic, and of others in tropical regions?

In Australia, New Zealand, and many other parts of the southern hemisphere, where the indigenous land quadrupeds are comparatively few and of small dimensions, the reptiles do not predominate in number or size. The deposits formed at the mouth of an Australian river, within the tropics, might contain the bones of only a few small marsupial animals, which, like those of Stonesfield, might heafter be discovered with difficulty by geologists; but there would, at the same time, be no megalosauri and other fossil remains, show-

ing that large saurians were plentiful on the land and in the waters when mammalia were scarce.

No precise analogy, therefore, can here be found to the state of the animal kingdom supposed to have prevailed during the secondary periods when a high temperature pervaded European latitudes. But it may be useful to consider whether any of the anomalies now caused by climate in the relative number and importance of different classes of the vertebrata may not in some degree illustrate this topic. In the Arctic regions, for example, reptiles are small, and sometimes wholly wanting, where birds, large land quadrupeds, and cetacea abound. We meet with bears, wolves, foxes, musk oxen, and deer, walrusses, seals, whales, and narwals, in regions of ice and snow, where the smallest snakes, efts, and frogs are rarely if ever seen.

On what grand laws in the animal physiology this remarkable phenomenon depends, cannot, in the present state of science, be explained; nor could we predict whether any opposite condition of the atmosphere in respect to heat, moisture, and other circumstances, would bring about a state of animal and vegetable life which might be called the converse of that above described. We ought, however, to recollect, that a mean annual temperature like that now experienced at the equator, co-existing with the unequal days and nights of European latitudes, and with a distinct distribution of sea and land, would imply a climate to which we have now no parallel. Consequently, the type of animal and vegetable existence required for such a climate might deviate as widely from that now established in any part of the globe, as do the Flora and Fauna of our tropical differ from those of our arctic regions.

Secondary fresh-water deposits, why rare. — If there were extensive tracts of land in the secondary period, we may presume that there were lakes also; yet I am not aware of any pure lacustrine formations interstratified with rocks older than the chalk. Perhaps their general absence may be accounted for by the adoption of the theoretical views above set forth; for if the present ocean coincides for the most part with the site of the ancient continent, the places occupied by lakes must have been submerged. It should also be recollected, that the area covered by lakes, at any one time, is very insignificant in proportion to the ocean; and, therefore, we may expect that, after the earth's surface has undergone considerable revolutions in its physical geography, the lacustrine strata will be concealed, for the most part, under superimposed marine deposits.

Persistency of mineral character. — In the same manner as it is rare and difficult to find ancient lacustrine strata, so also we can scarcely expect to discover newer marine groups preserving the same lithological characters continuously throughout wide areas. The chalk now seen stretching for thousands of miles over different parts of Europe has become visible to us by the effect, not of one, but of many distinct series of movements. Time has been required, and a succession of geological periods, to raise it above the waves in so many regions; and if calcareous rocks of the Eocene or Miocene periods have been formed, preserving a homogeneous mineral composition throughout equally extensive regions, it may require convulsions as numerous as all those which have occurred since the origin of the chalk to bring them up within the sphere of human observation. Hence the rocks of more modern

periods may appear of partial extent, as compared to those of remoter eras, not because there was any original difference of circumstances throughout the globe when they were formed, but because there has not been sufficient time for the development of a great series of subterranean volcanic operations since their origin.

At the same time, the reader should be warned not to place implicit reliance on the alleged persistency of the same mineral characters in secondary rocks.* When it was first ascertained that an order of succession could be traced in the principal groups of strata above enumerated, names were given to each, derived from the mineral composition of the rocks in those parts of Germany, England, or France, where they happened to be first studied. When it was afterwards acknowledged that the zoological and phytological characters of the same formations were far more persistent than their mineral peculiarities, the older names were still retained, instead of being exchanged for others founded on more constant and essential characters. The student was given to understand that the terms chalk, green-sand, oolite, red marl, coal, and others, were to be taken in a liberal and extended sense; that chalk was not always a cretaceous rock, but in some places, as on the northern flanks of the Pyrenees, and in Catalonia, a saliferous red marl. Green-sand, it was said, was rarely green, and frequently not arenaceous, but represented in parts of the south of Europe by a hard dolomitic limestone. In like manner, it was declared that the oolitic texture was rather an exception to the general rule in rocks of the oolitic

* See some remarks on this subject, Vol. I. p. 132.

period, and that no particle of carbonaceous matter could often be detected in the true *coal* formation of many districts where it attains great thickness. It must be obvious to every one, that inconvenience and erroneous prepossessions could hardly fail to arise from such a nomenclature; and accordingly a fallacious mode of reasoning has been widely propagated, chiefly by the influence of a language so singularly inappropriate.

After the admission that the identity or discordance of mineral character was by no means a sure test of agreement or disagreement in the age of rocks, it was still thought, by many geologists, that if they found a rock at the antipodes agreeing precisely in mineral composition with another well known in Europe, they could fairly presume that both are of the same age, *until the contrary could be shown.*

Now, it is usually difficult or impossible to combat such an assumption on geological grounds, so long as we are imperfectly acquainted with the geology of a distant country, inasmuch as there are often no organic remains in the foreign stratum; and even if these abound, and are specifically different from the fossils of supposed European equivalent, it may be objected that the we cannot expect the same species to have inhabited very distant quarters of the globe at the same time.

Supposed universality of red marl. — I shall select a remarkable example of the erroneous mode of generalizing now alluded to. A group of red marl and sandstone, sometimes containing salt and gypsum, is found in England interposed between the lias and the carboniferous strata. For this reason, other red marls and sandstones, associated some of them with salt, and

others with gypsum, and occurring not only in different parts of Europe, but in Peru, India, the salt deserts of Asia, those of Africa, in a word, in every quarter of the globe, have been referred to one and the same period. The burden of proof is not supposed to rest with those who insist on the identity of age of all these groups; so that it is in vain to urge as an objection the improbability of the hypothesis which would imply that all the moving waters on the globe were once simultaneously charged with sediment of a red colour.

The absurdity of pretending to identify, in age, all the red sandstones and marls in question, has at length been sufficiently exposed, by the discovery that, even in Europe, they belong decidedly to many different epochs. We have already ascertained, that the red sandstone and red marl, with which the rock-salt of Cardona is associated, may be referred to the period of our chalk and green-sand. I was led to this opinion when I visited Cardona in 1830, and before I was aware that M. Dufrénoy had arrived at the same conclusions.* I have pointed out that in Auvergne there are red marls and variegated sandstones, which are undistinguishable in mineral composition from the new red sandstone of English geologists, yet which were deposited in the Eocene period: and, lastly, the gypseous red marl of Aix, in Provence, formerly supposed to be a marine secondary group, is now acknowledged to be a tertiary fresh-water formation.

Secondary rocks, why more consolidated. — One of the points where the analogy between the secondary and tertiary formations has been supposed to fail, is the greater degree of solidity observable in the secondary

* Ann. des Sci. Nat., Avril, 1831, p. 449.

s eris. Undoubtedly the older rocks, in general, are more stony than the newer; and most of the tertiary strata are more loose and incoherent in their texture than the secondary. Many exceptions, however, may be pointed out, especially in those calcareous and siliceous deposits which have been precipitated in great part from the waters of mineral springs, and have been originally compact. Of this description are a large proportion of the Parisian Eocene rocks, which are more stony than most of the English secondary groups.

But strata in general have evidently been consolidated *subsequently to their deposition* by a slow lapidifying process. Thus loose sand and gravel are bound together by waters holding carbonate and oxide of iron, carbonate of lime, silica, and other ingredients in solution. These waters percolate slowly the earth's crust in different regions, and often remove gradually the component elements of fossil organic bodies, substituting other substances in their place. It seems, moreover, that the draining off of the waters during the elevation of land may often cause the *setting* of particular mixtures, in the same manner as mortar hardens when desiccated, or as the recent soft marl of Lake Superior becomes highly indurated when exposed to the air.* The conversion of clay into shale, and of sand into sandstone, may, in many cases, be attributed to simple pressure, produced by the weight of superincumbent strata, or by the upward heaving of subjacent masses during earthquakes. Heat is another cause of a more compact and crystalline texture, which will be considered when I speak of the strata termed "primary." All the changes produced by these various

* Vol. I. p. 340.

means require *time* for their completion; and this may explain, in a satisfactory manner, why the older rocks are most consolidated, without entitling us to resort to any hypothesis respecting an *original* distinctness in the degree of lapidification of the secondary strata.

Secondary, why more disturbed. — As the older formations are generally more stony, so also they are more fractured, curved, elevated, and displaced, than the newer. Are we, then, to infer, with some geologists, that the disturbing forces were more energetic in remoter ages? No conclusion can be more unsound; for as the moving power acts from below, the newer strata cannot be deranged without the subjacent rocks participating in the movement; while we have evidence that the older have been frequently shattered, raised, and depressed, again and again, before the newer rocks were formed. It is evident that if the disturbing power of the subterranean causes be exerted with *uniform* intensity in each succeeding period, the quantity of convulsion undergone by different groups of strata will generally be great in proportion to their antiquity. But exceptions will occur, owing to the partial operation of the volcanic forces at particular periods; so that we sometimes find tertiary strata more elevated and disturbed, in particular countries, than the secondary rocks in others.

Some of the enormous faults and complicated dislocations of the ancient strata may probably have arisen from the continued repetition of earthquakes in the same place, and sometimes from two distinct series of convulsions, which have forced the same masses in different, and even opposite directions; sometimes by vertical, at others by horizontal movements.

Secondary volcanic rocks of different ages. — The association of volcanic rocks with different secondary strata is such as to prove that there were igneous eruptions at many distinct periods, as also that they were confined during each epoch, as now, to limited areas. Thus, for example, igneous rocks contemporaneous with the carboniferous strata abound in some countries, but are wanting in others. So it is evident that the bottom of the sea, on which the oolite and its contemporary deposits were thrown down, was, for the most part, free from submarine eruptions; but at some points, as in the Hebrides, it seems that the same ocean was the theatre of volcanic action. It was before remarked*, that, as the ancient eruptions occurred in succession, sufficient time usually intervening between them to allow of the accumulation of many subaqueous strata, so also should we infer that subterranean movements, which are another portion of the volcanic phenomena, occurred separately and in succession.

* Book i. chap. v.

CHAPTER XXV.

RELATIVE ANTIQUITY OF MOUNTAIN-CHAINS.

Theory of M. Elie de Beaumont — His opinions controverted — His method of proving that different chains were raised at distinct periods, and that the rise of others was contemporaneous, not conclusive — His doctrine of the parallelism of contemporaneous lines of elevation — Objections (p. 333.) — How far anticlinal lines formed at the same period are parallel — Difficulties in the way of determining the relative age of mountains.

That the different parts of our continents have been elevated, in succession, to their present height above the level of the sea, is an opinion which has been gradually gaining ground with the progress of science; but no one before M. Elie de Beaumont had the merit even of attempting to collect together the recorded facts which bear on this subject, and to reduce them to one systematic whole. The above-mentioned geologist was eminently qualified for the task, as one who had laboured industriously in the field of original observation, and who combined an extensive knowledge of facts with an ardent love of generalization.

But, as I cannot admit the accuracy of an important part of his method of reasoning on this topic, and as his principal conclusions appear to me very uncertain, I must explain the reasons of my dissent, having first given a brief summary of the most prominent features of his theory.

1st. M. de Beaumont supposes, "that in the history of the earth there have been long periods of comparative repose, during which the deposition of sedimentary matter has gone on in regular continuity; and there have also been short periods of paroxysmal violence, during which that continuity was broken.

"2dly. At each of these periods of violence or 'revolution' in the state of the earth's surface, a great number of mountain-chains have been formed suddenly.

"3dly. All the chains thrown up by a particular revolution have one uniform direction, being parallel to each other within a few degrees of the compass, even when situated in remote regions; but the chains thrown up at different periods have, for the most part, different directions.

"4thly. Each 'revolution,' or, as it is sometimes termed, 'frightful convulsion,' has fallen in with the date of another geological phenomenon; namely, 'the passage from one independent sedimentary formation to another,' characterized by a considerable difference in 'organic types.'

"5thly. There has been a recurrence of these paroxysmal movements from the remotest geological periods; and they may still be reproduced, and the repose in which we live may hereafter be broken by the sudden upthrow of another system of parallel chains of mountains.

"6thly. We may presume that one of these revolutions has occurred within the historical era, when the Andes were upheaved to their present height; for that chain is the best defined and least obliterated feature observable in the present exterior configuration of the globe, and was probably the last elevated.

"7thly. The instantaneous upheaving from the ocean of great mountain masses must cause a violent agitation in the waters; and the rise of the Andes may, perhaps, have produced that transient deluge which is noticed among the traditions of so many nations.

"Lastly. The successive revolutions above mentioned cannot be referred to ordinary volcanic forces, but may depend on the secular refrigeration of the heated interior of our planet."*

I need not enter here into an examination of all these topics, as the discussion of several of them has been in some degree anticipated in former chapters. Respecting the alternation of periods of general repose and disorder, I have before suggested that geological phenomena indicate merely that each region of the globe has in succession been a great theatre of subterranean convulsions, as some districts are now, while others remain at rest. Before we can reasonably attribute extraordinary energy to any known cause, we must be sure that its usual force would be inadequate, though exerted for indefinite ages, to produce the effects required.

The geologist, therefore, who assumes that continents and mountain-chains have been heaved up suddenly by paroxysmal violence, may be considered as pledging himself to the opinion that the accumulated effects of ordinary volcanic forces could never in any series of years produce appearances such as we witness in the earth's crust. Time and the progress of

* Ann. des Sci. Nat., Septembre, Novembre, et Décembre, 1829. Revue Française, No. 15. May, 1830. The last edition by M. de B. is in De la Beche's Manual, 3d. edit.; and D'Aubuisson, Traité de Géognosie, tom. iii. p. 282., 1835.

science can alone decide whether such an assumption is warranted, or whether, on the contrary, it does not spring from two sources of prejudice: — first, the difficulty of conceiving the aggregate results of a great number of minor convulsions; secondly, the habit of viewing geological phenomena without any desire to explain them as the effects of moderate forces, such as we know to act, instead of that intense degree of energy, the occasional development of which, however possible, is entirely conjectural.

The speculation of M. de Beaumont concerning the "secular refrigeration" of the internal nucleus of the globe, considered as a cause of the instantaneous rise of mountain-chains, appears to me obscure, and is mainly founded on that part of the doctrine of central heat which has been controverted in the second volume.*

In regard to the connection of the rise of mountain-chains with revolutions equally sudden in the animate world, I have endeavoured to show, in the third book, that changes in physical geography, which are unceasingly in progress, are among the causes which contribute, in the course of ages, to the extermination of certain species of animals and plants; but the influence of these causes is slow, and, for the most part, indirect, and has no analogy with those sudden catastrophes which are introduced into the theory now under review. An explanation of the probable cause of the abrupt transitions from one set of strata to another, containing distinct organic remains, has been given at length in the third and fourth chapters of this book.†

* Book ii. chapters xviii. and xix.

† See particularly from p. 367. to p. 377. of Vol. III.

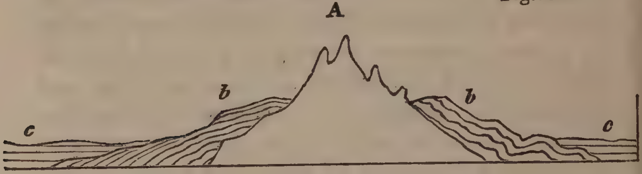
When the protrusion of the Andes from beneath the sea is proposed as a possible cause of the historical delüge, we naturally inquire, what proofs there are of that chain having started up at once within the last 4000 or 5000 years from a great depth of sea; for it is necessary that a large body of water should be displaced, in order that a diluvial wave, capable of inundating a previously existing continent, should be raised. If it were reasonable to refer deluges to what have been called paroxysmal elevations, it would surely be a fairer speculation to point to a line of shoals or reefs, consisting of shattered and dislocated rocks, and surrounded on all sides by an unfathomable ocean, than to select a mountain-chain as the site of the upthrow; for the rapid conversion of the bed of a deep sea into a shoal would evidently cause a much greater displacement of water than the rise of a large shoal into a mountain-chain.

Without dilating further on these subjects, I shall now endeavour to analyze the proofs by which the successive elevation of different chains, and the supposed parallelism of lines of contemporaneous elevation, are supported.

M. de Beaumont's proofs that different chains were raised at different epochs.—"We observe," says M. Elie de Beaumont, "along nearly all the mountain-chains, when we attentively examine them, that the most recent rocks extend horizontally up to the foot of such chains, as we should expect would be the case if they were deposited in seas or lakes, of which these mountains have partly formed the shores; whilst the other sedimentary beds tilted up, and more or less contorted, on the flanks of the mountains, rise in cer-

tain points even to their highest crests."* There are, therefore, in and adjacent to each chain, two classes of sedimentary rocks, the ancient or inclined beds, and the newer or horizontal. It is evident that the first appearance of the chain itself was an event "intermediate between the period when the beds now upraised were deposited and that when the strata were produced horizontally at its feet."

Fig. 154.



Thus the chain A assumed its present position after the deposition of the strata *b*, which have undergone great movements, and before the deposition of the group *c*, in which the strata have not suffered derangement.

If we then discover another chain, B, in which we

Fig. 155.

find not only the formation *b*, but the group *c* also, disturbed and thrown on its edges, we may infer that the latter chain is of subsequent date to A; for B must have been elevated *after* the deposition of *c*, and before that of the group *d*; whereas A had originated *before* the strata *c* were formed.

* Phil. Mag. and Annals, No. 58., New Series, p. 242.

In order to ascertain whether other mountain ranges are of contemporaneous date with A and B, or are referrible to *distinct* periods, we have only to inquire whether the geological phenomena are identical; namely, whether the inclined and undisturbed sets of strata in each correspond to those in the types above mentioned.

Objections to M. de Beaumont's theory.—Now all this reasoning is perfectly correct, so long as the periods of the deposition of the particular local groups of strata *b* and *c* are not confounded with the periods during which the animals and plants found fossil in *b* and *c* may have flourished, and provided also that due latitude is given to the term contemporaneous; for this term must be understood to allude, not to a moment of time, but to the interval, whether brief or protracted, which elapsed between two events, namely, between the accumulation of the inclined and that of the horizontal strata.

But, unfortunately, no attempt seems to have been made to avoid this manifest source of confusion, and hence the very terms of each proposition are equivocal; and the length of some of the intervals is so vast, that to affirm that all the chains raised in such intervals were *contemporaneous*, is an abuse of language.

In order to illustrate this argument, I shall select the Pyrenees as an example. This range of mountains, says M. de Beaumont, rose suddenly (à un seul jet*) to its present elevation at a certain epoch in the

* In the last edition of M. de B.'s system (see note above, p. 329.), he only speaks of the convulsion which raised the Pyrenees, as "one of the most violent which the land of Europe ever experienced."

earth's history, namely, between the deposition of the chalk and that of the tertiary formations; for the chalk is seen in vertical, curved, and distorted beds on the flanks of the chain, while the tertiary formations rest upon them in horizontal strata at its base.

The only proof offered of the extreme suddenness of the convulsion is the shortness of the time which intervened between the formation of the chalk and that of the tertiary strata.*

Now the beds called chalk on the flanks of the Pyrenees differ widely in mineral composition from the white chalk with flints of England and France; but as they contain for the most part the same species of fossil shells, I grant that they may on that evidence be referred to the cretaceous system.† On the other hand, the horizontal tertiary strata at the western end of the Pyrenees, near Bayonne, are certainly of the Miocene period. The reader will find, when he reflects on these data, that we can only infer that the great movement took place after the cretaceous period had commenced, but we cannot assume that it occurred after the *close* of that period. So also we may say, that the Pyrenees rose before the close of the Miocene epoch, but not that the event happened before its *commencement.* We cannot permit M. de Beaumont to exclude the whole of either of these periods (the Cretaceous and Miocene) from the possible duration of that interval during all or any part of which the elevation may have taken place.

* Phil. Mag. and Annals, No. 58., New Series, p. 243.

† The fossils which I collected in company with Captain S. E. Cook, R. N., from the newest secondary beds on the flanks of the Pyrenees, near Bayonne, were examined by M. Deshayes, and found identical with species of the chalk near Paris.

The upheaving of the Pyrenees, therefore, may have been going on before the animals of the chalk period ceased to exist, or when the Maestricht beds were in progress, or during the indefinite ages which may have elapsed between the extinction of the Maestricht animals and the introduction of the Eocene tribes, or during the Eocene epoch, or between that and the Miocene, or at the commencement of the Miocene epoch. Or the rise may have been going on throughout one, or several, or all of these periods.

It would be a purely gratuitous assumption to say that the chalk strata *c*, Fig. 155., p. 332., were the last which were deposited during the cretaceous period, or that, when they were upheaved, all or nearly all the species of animals and plants which are now found fossil in them were suddenly exterminated: yet, unless this can be affirmed, we cannot say that the chain B was not upheaved during the cretaceous period. Consequently, another range of mountains (A, Fig. 154.), at the base of which cretaceous rocks, *c*, may lie in horizontal stratification, may have been elevated during the same period; because, in this case, the particular group *c* may have been formed long after the animals and plants which are characteristic of them, in a fossil state, began to flourish, and during those antecedent ages the chain A may have risen.

The Newer Pliocene strata in Sicily have been raised to the height of nearly 3000 feet in some places, with great derangement; yet the testacea and zoophytes inclosed in these still exist, or nine tenths of them at least, in the Mediterranean. The same period still continues, if we speak of periods in the same extended sense in which they are understood by geologists, and by M. de Beaumont, in the memoir now

before us. So the chalk in the Pyrenees may have been raised to the height of many thousand feet, when the animals found fossil in the upheaved strata still continued to inhabit the sea.

In like manner the sea may have been inhabited by Miocene testacea for ages before the deposition of those particular Miocene strata which occur at the foot of the Pyrenees.

To illustrate the grave objections above advanced, which go to affect the whole of De Beaumont's reasoning, let us suppose, that in some country three styles of architecture had prevailed in succession, each for a period of one thousand years; first the Greek, then the Roman, and then the Gothic; and that a tremendous earthquake was known to have occurred in the same district during some part of the three periods,—a shock of such violence as to have levelled to the ground all the buildings then standing. If an antiquary, desirous of discovering the date of the catastrophe, should first arrive at a city where several Greek temples were lying in ruins and half engulphed in the earth, while many Gothic edifices were standing uninjured, could he determine on these data the era of the shock? Certainly not. He could merely affirm that it happened at some period after the introduction of the Greek style, and before the Gothic had fallen into disuse. Should he pretend to define the date of the convulsion with greater precision, and decide that the earthquake must have occurred in the interval between the Greek and Gothic periods, that is to say, when the Roman style was in use, the fallacy in his reasoning would be too palpable to escape detection for a moment.

Yet such is the nature of the erroneous induction

which I am now exposing. For, as in the example above proposed, the erection of a particular edifice is perfectly distinct from the period of architecture in which it may have been raised, so is the deposition of chalk, or any other set of strata, from the geological epochs characterized by certain fossils to which they may belong.

It is superfluous to enter into any farther analysis of this theory, because the force of the whole argument depends on the accuracy of the data by which the contemporaneous or non-contemporaneous date of the elevation of two independent chains can be demonstrated. In every case, this evidence, as stated by M. de Beaumont, is equivocal, because he has not included in the possible interval of time between the deposition of the deranged and the horizontal formations part of the periods to which each of those classes of formations are referrible. By the insufficiency, then, of the above proofs, the doctrine of the parallelism of lines of contemporaneous elevation is destroyed; because all the geological facts may be true, and yet the conclusion that certain chains were or were not simultaneously upraised is by no means a legitimate consequence.

As the hypothesis of parallelism, however, has acquired some popularity, I may remark, that it appears, as stated by the author, to be in some degree at variance with itself. When certain European chains were assumed to have been raised at the same time, on the data already impugned, it was found that several of these contemporaneous chains had a parallel direction. Hence it was immediatedy inferred to be a general law in geological dynamics that the chains upheaved at the same time are parallel. For example, it was said

that the Pyrenees and northern Apennines have a direction about W. N. W. and E. S. E.; to this line the Alleghanies, in North America, conform, as also the Ghauts of Malabar, and certain chains in Egypt, Syria, northern Africa, and other countries; and from this mere conformity in direction it was presumed that all these mountain-ranges were thrown up simultaneously.*

To select another example, the principal chain of the Alps, differing in age and direction from the Pyrenees, is parallel to the Sierra Morena, the Balkan, the chain of Mount Atlas, the central chain of the Caucasus, and the Himalaya. All these ridges, therefore, are assumed to have been heaved up by the same paroxysmal convulsion. The western Alps, on the other hand, rose at a still earlier period, when the parallel chains of Kiöl, in Scandinavia, certain chains in Morocco, and the littoral Cordillera of Brazil, were formed!

Not only do these speculations refer to mountains never yet touched, as M. Boué remarks, by the hammer of the geologist, but they proceed on the supposition, that in these distant chains the geological and geographical axes always coincide. Now we know that in Europe the *strike* † of the beds is not always parallel to the direction of the chain. As an exception, we

* In regard to the Alleghanies, see De Beaumont, 1833. French Trans. of De la Beche's Manual, p. 657. But in fact this chain runs from N. E. to S. W.

† The term "strike" has been recently adopted by some of our most eminent geologists from the German "streich," to signify what our miners call the "line of bearing" of the strata. Such a term was much wanted; and, as we often speak of *striking off* in a given direction, the expression seems sufficiently consistent with analogy in our language.

may instance the Hartz mountains, where Von Dechen * states that the direction or *strike* of the strata of slate and greywacké is sometimes from E. and W., and frequently N. E. and S. W.; the geographical direction of the mountain-chain being decidedly from E. S. E. to W. N. W.

In addition to these considerations, the important admission is made by M. de Beaumont himself, that the elevating forces, whose activity must be referred to *different* epochs, have sometimes acted in Europe in *parallel* lines. "It is worthy of remark," he says, "that the directions of three systems of mountains, —namely, first, that of the Pilas and the Côte d'Or; secondly, that of the Pyrenees; and thirdly, that of the islands of Corsica and Sardinia,—are respectively parallel to three other systems, namely, first, that of Westmoreland and the Hunsdruck; secondly, that of the Ballons (or Vosges) and the hills of the Bocage, in Calvados; and thirdly, the system of the north of England. The corresponding directions only differ in a few degrees, and the two series have succeeded each other in the same order, leading to the supposition, that there has been *a kind of periodical recurrence* of the same, or nearly the same, directions of elevations." †

Here then, we have three systems of mountains, A, B, C, which were formed at successive epochs, and have each a different direction; and we have three other systems, D, E, F, which, although they are assumed to have the same strike as the series first mentioned, (D corresponding with A, E with B, and

* Trans. of De la Beche's Geol. Manual, p. 41.

† Phil. Mag. and Annals, No. 58., New Series, pp. 255, 256.

F with C,) are nevertheless declared to have been formed at different periods. On what principle, then, is the age of an Indian or transatlantic chain referred to one of these European lines rather than to another? — why is the age of the Alleghanies, or the Ghauts of Malabar, determined by their parallelism to B rather than to E, to the Pyrenees rather than to the Ballons of the Vosges? *

Modern volcanic lines not parallel. — The analogy of volcanic operations in our own times would lead us to suppose that the lines of convulsion, at former epochs, were far from being uniform in direction; for that the trains of *active* volcanos are not parallel, every one is aware who has studied Von Buch's masterly survey of the general range of volcanic lines over the globe †; while the elevations and subsidences caused by modern earthquakes, although they may sometimes run in parallel lines within limited districts, have not been observed to have a common direction in distant and independent theatres of volcanic action.

I doubt not that in many regions, yet only within a limited range of country, the ridges, troughs, and fissures caused by modern earthquakes are, to a certain extent, parallel to each other; and such appears to have been the case in many districts at former eras.

* The substance of the last objection has been anticipated by M. Boué (Journ. of Geol., tom. iii. p. 338.). I shall not repeat here minor points and facts, enumerated, in a former edition, as disputed by several geologists, because they are of no importance, if the basis of the theory is unfounded. See Mr. Conybeare's remarks, Phil. Mag. and Journ. of Sci., No. 2., Third Series, p. 118. Studer, Bulletin de la Soc. Géol. de France, ii. p. 68.

† Physical. Besch. der Canarischen Inseln. Berlin, 1825.

The anticlinal lines of the Weald valley, before alluded to, and of the Isle of Wight, may, in this manner, have been contemporaneous; that is to say, both may have been formed in some part of the Eocene period, — an hypothesis which does not involve the theory of their having been due to a paroxysmal convulsion at the same moment of that vast period. It should be observed, that, as some trains of burning volcanos are parallel to each other, so at all periods some independent lines of elevation may be parallel *accidentally;* not in obedience to any known law of parallelism; but, on the contrary, as exceptions to the general rule.

The speculations of M. de Beaumont will, I trust, be useful in inducing geologists to inquire how far the uniformity in the direction of the beds, in a region which has been agitated at any particular period, may extend; but, in the present state of our science, I cherish no sanguine expectations of fixing a chronological succession of epochs of elevation of different mountain-chains, or of making more than a loose approximation to such a result. The difficulty depends chiefly on the broken and interrupted nature of the series of sedimentary formations hitherto brought to light, which appears so imperfect that we can very seldom be sure that, between the groups now classed as consecutive, the memorials of some great interval of time may not be wanting. Another great source of ambiguity arises from the small progress which we have yet made in identifying strata in countries somewhat distant from each other.

There may be instances, perhaps, where the same set of strata, preserving throughout a perfect identity of mineral character, may be traced continuously from

the flanks of one independent mountain-chain to the base of another, the beds being vertical or inclined in one chain, and horizontal in the other. We might then decide with confidence, according to the method proposed by M. de Beaumont, on the relative periods at which these chains had undergone disturbance; and from one point thus securely established, we might proceed to another, until we had determined the eras of many neighbouring lines of convulsion.

CHAPTER XXVI.

ON THE ROCKS COMMONLY CALLED "PRIMARY."

Relation of rocks called "Primary" to volcanic and sedimentary formations — Unstratified rocks called "Plutonic" — Granite veins — Their various forms and mineral composition — Proofs of their igneous origin — Granites of the same character produced at successive eras (p. 350.) — Some of these newer than certain fossiliferous strata — Volcanic, trappean, and plutonic rocks.

I SHALL now treat of the class of rocks usually termed "primary," a name which, as I shall afterwards show, is not always applicable, since the formations so designated sometimes belong to different epochs, and are not, in every case, more ancient than the fossiliferous strata. In general, however, this division of rocks may justly be regarded as of higher antiquity than the secondary and transition groups above described; and they may, therefore, with propriety be spoken of in these concluding chapters, as I have hitherto proceeded in my retrospective survey from the newer to the more ancient geological monuments.

In order to explain the relation which I conceive the rocks termed "primary" to bear to the tertiary, secondary, and transition formations, I shall resume that general view of the component parts of the earth's crust of which I gave a slight sketch in the preliminary division of the subject in the second chapter.*

* See Vol. III. pp. 335, 336.

It was there stated that sedimentary formations, containing organic remains, occupy a large part of the surface of our continents; but that here and there volcanic rocks occur, covering, alternating with, or breaking through, the sedimentary deposits; so that there are two orders of mineral masses formed at the surface, which have obviously a distinct origin, — the aqueous and the volcanic.

Fig. 156.

a. Formations called primary (stratified and unstratified).
b. Aqueous formations. *c.* Volcanic rocks.

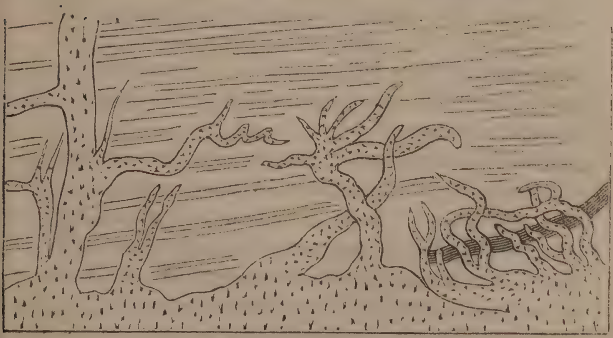
Besides these, however, there is another class, which cannot be assimilated precisely to either of the preceding, and which is often seen underlying the sedimentary, or breaking up to the surface in the central parts of mountain-chains, constituting some of the highest lands, and, at the same time, passing down and forming the inferior parts of the crust of the earth. This class, usually termed "primary," is divisible into two groups,— the stratified and the unstratified. The stratified consists of the rocks called gneiss, mica-schist, argillaceous-schist (or clay-slate), hornblende schist, primary limestone, and some others. The unstratified, or Plutonic, is composed in great measure of granite, and rocks closely allied to granite. Both these groups agree in having, for the most part, a highly crystalline texture, and in not containing organic remains.

Plutonic rocks. — The unstratified crystalline rocks have been very commonly called Plutonic, from the

opinion that they were formed by igneous action at great depths; whereas the volcanic, although they also have risen up from below, have cooled from a melted state upon or near to the surface. Granite, porphyry, and other rocks of the same family, often occur in large amorphous masses, from which small veins and dikes are sent off, which traverse the stratified rocks called "primary," precisely in the manner in which lava is seen in some places to penetrate the secondary strata.

Granite veins. — We find also one set of granite veins intersecting another, and granitiform porphyries intruding themselves into granite, in a manner analogous to that of the volcanic dikes of Etna and Vesuvius, where they cut and shift each other, or pass through alternating beds of lava and tuff.

Fig. 157.



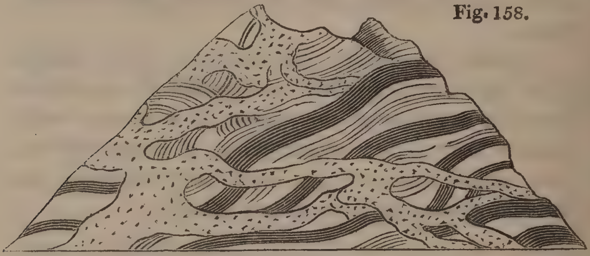
Granite veins traversing stratified rocks.

The annexed diagram will explain to the reader the manner in which these granite veins often branch off from the principal mass. Those on the right-hand side, and in the middle, are taken from Dr. Maccul-

loch's representation of veins passing through the gneiss at Cape Wrath, in Scotland. * The veins on the left of the same diagram are described, by Captain Basil Hall, as traversing the argillaceous schist of the Table-Mountain at the Cape of Good Hope.†

I subjoin another sketch from Dr. Macculloch's interesting representations of the granite veins in Scotand, in which the contrast of colour between the vein

Fig. 158.



Granite veins traversing gneiss at Cape Wrath, in Scotland.

and some of the dark varieties of hornblende-schist associated with the gneiss renders the phenomena more conspicuous.

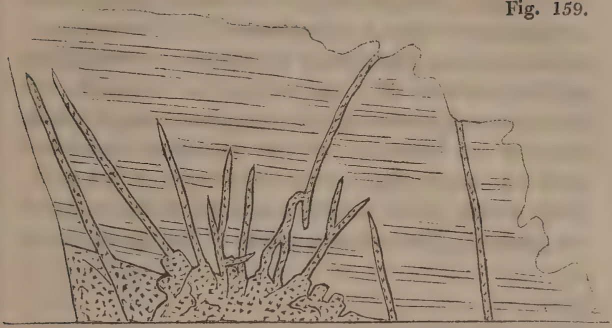
The following sketch of a group of granite veins in Cornwall is given by Messieurs Von Oeynhausen and Von Dechen.‡ The main body of the granite here is of a porphyritic appearance, with large crystals of felspar; but in the veins it is fine-grained, and without these large crystals. The general height of the veins is from sixteen to twenty feet, but some are much higher.

* Western Islands, plate 31.

† Account of the Structure of Table-Mountain, &c. Trans. Roy. Soc. Edin., vol. vii.

‡ Phil. Mag. and Annals, No. 27., New Series, March, 1829.

Fig. 159.



Granite veins passing through hornblende slate, Carnsilver Cove, Cornwall.

The vein-granite of Cornwall very generally assumes a finer grain, and frequently undergoes a change in mineral composition, as is very commonly observed in other countries. Thus, according to Professor Sedgwick, the main body of the Cornish granite is an aggregate of mica, quartz, and felspar; but the veins are sometimes without mica, being a granular aggregate of quartz and felspar. In other varieties quartz prevails to the almost entire exclusion both of felspar and mica; in others, the mica and quartz both disappear, and the vein is simply composed of white granular felspar.*

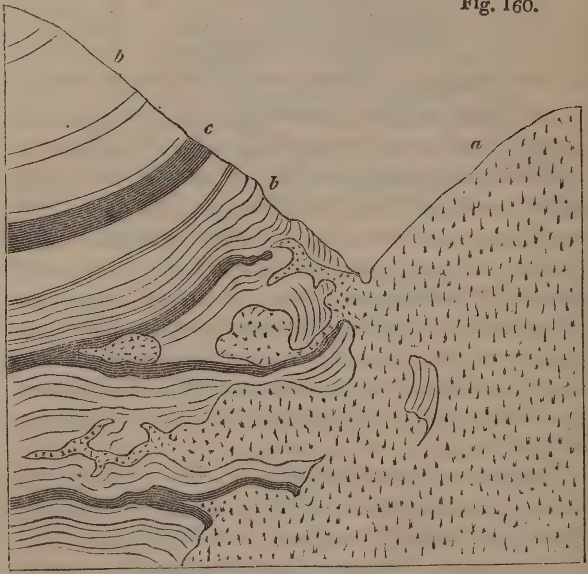
Changes are sometimes caused in the intersected strata very analogous to those which the contact of a fused mass might be supposed to produce.

The annexed diagram, from a sketch of Dr. Macculloch, represents the junction of the granite of Glen Tilt, in Perthshire, with a mass of stratified limestone

* On Geol. of Cornwall, Trans. of Cambridge Soc., vol. i. p. 124.

and schist. The granite, in this locality, often sends forth so many veins as to reticulate the limestone and schist, the veins diminishing towards their termination to the thickness of a leaf of paper or a thread. In some places fragments of granite appear entangled, as it were, in the limestone, and are not visibly connected with any larger mass; while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite. The ordinary colour of the limestone of

Fig. 160.



Junction of granite and limestone in Glen Tilt.

a. Granite. *b.* Limestone.
c. Blue argillaceous schist.

Glen Tilt is lead blue, and its texture large-grained and highly crystalline; but where it approximates to

the granite, particularly where it is penetrated by the smaller veins, the crystalline texture disappears, and it assumes an appearance exactly resembling that of horn-stone. The associated argillaceous schist often passes into hornblende slate, where it approaches very near to the granite.*

The conversion of the limestone in these and many other instances into a siliceous rock, effervescing slowly with acids, would be difficult of explanation, were it not ascertained that such limestones are always impure, containing grains of quartz, mica, or felspar disseminated through them. The elements of these minerals, when the rock has been subjected to great heat, may have been fused, and so spread more uniformly through the whole mass.

In the plutonic, as in the volcanic rocks, there is every gradation from a tortuous vein to the most regular form of a dike, such as I have described intersecting the tuffs and lavas of Vesuvius and Etna. In these dikes of granite, which may be seen, among other places, on the southern flank of Mount Battoch, one of the Grampians, the opposite walls sometimes preserve an exact parallelism for a considerable distance. It is not uncommon for one set of granite veins to intersect another; and sometimes there are three sets, as in the environs of Heidelberg, where the granite on the banks of the river Necker is seen to consist of three varieties, differing in colour, grain, and various peculiarities of mineral composition. One of these, which is evidently the second in age, is seen to cut through an older granite; and another, still newer, traverses both the second and the first. These pheno-

* Macculloch, Geol. Trans., vol. iii. p. 259.

mena were pointed out to me by Professor Leonhard at Heidelberg.

In Shetland there are two kinds of granite. One of these, composed of hornblende, mica, felspar, and quartz, is of a dark colour, and is seen underlying gneiss. The other is a red granite, which penetrates the dark variety every where in veins.*

Granites of different ages.—It was formerly supposed that granite was the oldest of rocks, the mineral product of a particular period or state of the earth, formed long antecedently to the introduction of organic beings into our planet. But it is now ascertained that this rock has been produced again and again, at successive eras, with the same characters, penetrating the stratified rocks in different regions, but not always associated with strata of the same age. Nor are organic remains always entirely wanting in the formations invaded by granite, although they are usually absent. Many well authenticated exceptions to the rule are now established, on the authority of numerous observers, amongst the earliest of whom we may cite Von Buch, who discovered in Norway a mass of granite overlying an ancient secondary limestone, containing orthocerata and other shells and zoophytes.†

A considerable mass of granite in the Isle of Sky is described by Dr. Macculloch as incumbent on limestone and shale, which are of the age of the English lias.‡ The limestone, which, at a greater distance from the granite, contains shells, exhibits no traces of

* Macculloch, Syst. of Geol., vol. i. p. 58.

† Travels through Norway and Lapland, p. 45. London, 1813.

‡ See Murchison, Geol. Trans., Second Series, vol. ii. part ii. pp. 311—321.

them near its junction, where it has been converted into a pure crystalline marble.*

This granite of Sky was at first termed "Syenite," by which name some authors have denominated the more modern granites; but they have entirely failed in their attempt to establish a distinction between granites and syenites on geological grounds. Syenite has been defined to be a triple compound of felspar, quartz, and hornblende; but the oldest granitiform rocks are very commonly composed of these ingredients only. In his later publications Dr. Macculloch has, with great propriety, I think, called the plutonic rock of Sky a granite.†

In different parts of the Alps a comparatively modern granite is seen penetrating through secondary strata, which contain belemnites, and other fossils, and are supposed to be referrible to the age of the English lias. According to the observations of MM. Elie de Beaumont and Hugi, masses of this granite are sometimes found partially overlying the secondary beds, and altering them in a manner analogous to the changes superinduced upon sedimentary deposits in contact with rocks of igneous origin.‡ (See Fig. 163. p. 376.)

In such examples we can merely affirm, that the granite is newer than a secondary formation containing belemnites; but we can form no conjecture when it originated, not even whether it be of secondary or tertiary date. It is not to be inferred that a granite is

* Western Islands, vol. i. p.330.

† Syst. of Geol., vol. i. p. 150.

‡ Elie de Beaumont, sur les Montagnes de l'Oisans, Mém. de la Soc. d'Hist. Nat. de Paris, tome. v. Hugi, Natur. Historische Alpenreise, Soleure, 1830.

usually of about the same age as the group of strata into which it has intruded itself; for in that case we should be inclined to assume, rashly, that the granite found penetrating a more modern rock, such as the lias, for example, was much newer than that which is found to invade greywacké. The contrary may often be true; for the plutonic rock which was last in a melted state may not anywhere have been forced up so near to the surface as to traverse the newer groups, but may be confined exclusively to the older sedimentary formations.

"In a deep series of strata," says Dr. Macculloch, "the superior or distant portions may have been but slightly disturbed, or have entirely escaped disturbance, by a granite which has not emitted its veins far beyond its immediate boundary. However certain, therefore, it may be, that any mass of granite is posterior to the gneiss, the micaceous schist, or the argillaceous schists, which it traverses, or into which it intrudes, we are unable to prove that it is not also posterior to the secondary strata that lie above them."*

There can be little doubt, however, that some granites are more ancient than any of our regular series which we identify by organic remains; because there are rounded pebbles of granite, as well as gneiss, in the conglomerates of very ancient fossiliferous groups.

Distinction between volcanic and plutonic rocks — Trap. — When geologists first began to examine attentively the structure of the northern parts of Europe, they were almost entirely ignorant of the phenomena of existing volcanos; and when they met with basalt

* Syst. of Geol., vol. i. p. 136.

and other rocks composed chiefly of augite, hornblende, and felspar, which are now admitted by all to have been once in a state of fusion, they were divided in opinion whether they were of igneous or of aqueous origin. In the sketch of the history of geology in the first volume, it was shown how much the polemical controversies on this subject retarded the advancement of the science, and how slowly the analogy of the rocks in question to the products of active volcanos was recognized.

Most of the igneous rocks first investigated in Germany, France, and Scotland were associated with marine strata, and in some places they occurred in tabular masses or platforms at different heights, so as to form on the sides of some hills a succession of terraces or *steps*; from which circumstance they were called "trap" by Bergman (from *trappa*, Swedish for a flight of steps), — a name afterwards adopted very generally into the nomenclature of the science.

When these trappean rocks were compared with lavas produced in the atmosphere, they were found to be in general less porous and more compact; and from this character, and their association with subaqueous deposits, the connection of their origin with ordinary volcanic action was overlooked. In this instance the terms of comparison were imperfect; for a set of rocks, formed almost entirely under water, was contrasted with another which had cooled in the open air.

Yet the products of the ancient volcanos of Central France were classed, in reference, probably, to their antiquity, with the trap rocks, although they afford perfect counterparts to existing volcanos, and were evidently formed in the open air. Mont Dor and the Plomb du Cantal, indeed, differ in many respects from

Vesuvius and Etna in the mineral constitution and structure of their lavas; but it is that kind of difference which we must expect to discover when we compare the products of any two active volcanos in distant regions, such as Teneriffe and Hecla, or Hecla and Cotopaxi.

The amygdaloidal structure in many of the trap formations proves that they were originally cellular and porous, like lava; but the cells have been subsequently filled up with silex, carbonate of lime, zeolite, and other ingredients which form the nodules. The absence of this amygdaloidal structure may be said to be one of the negative characters of granite and other plutonic rocks.

Dr. Macculloch, after examining with great attention the igneous rocks of Scotland, observes, "that it is a mere dispute about terms to refuse to the ancient eruptions of trap the name of submarine volcanos, for they are such in every essential point, although they no longer eject fire and smoke." * The same author also considers it not improbable that some of the volcanic rocks of the same country may have been poured out in the open air.†

The recent examination of the igneous rocks of Sicily, especially those of the Val di Noto, has proved that all the more ordinary varieties of European trap have been produced under the waters of the sea in the Newer Pliocene period; that is to say, since the Mediterranean has been inhabited by a great proportion of the existing species of testacea. We are, therefore, entitled to expect, that if we could obtain access to the existing bed of the ocean, and explore the igneous

* Syst. of Geol., vol. ii. p. 114. † Ibid.

rocks poured out within the last five thousand years beneath the pressure of a sea of considerable depth, we should behold formations of modern date very similar to the most ancient trap rocks of our island. We cannot, however, expect the identity to be perfect; for time is ever working some alteration in the composition of these mineral masses, as, for example, by converting porous lava into amygdaloids.

Passage from trap into granite. — If a division be attempted between the trappean and volcanic rocks, it must be made between different parts of the same volcano, — nay, even the same rock, which would be called "trap," where it fills a fissure and has assumed a solid crystalline form on slow cooling, must be termed volcanic, or lava, where it issues on the flanks of the mountain. Some geologists may, perhaps, be of opinion that melted matter, which has been poured out in the open air, may be conveniently called volcanic; while that which appears to have cooled at the bottom of the sea, or under pressure, but at no great depth from the surface, may be termed "trap:" but it is very doubtful whether such distinctions can be made without confusion, and whether we shall not be obliged to consider trap and volcanic as synonymous. On the other hand, the difficulty of discriminating the volcanic from the plutonic rocks is sufficiently great; there being an insensible passage from the most common forms of granite into trap or lava.

"The ordinary granite of Aberdeenshire," says Dr. Macculloch, "is the usual ternary compound of quartz, felspar, and mica; but sometimes hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of felspar and hornblende; and in examining more minutely this

duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into a basalt, and at length into a soft claystone, with a schistose tendency on exposure, in no respect differing from those of the trap islands of the western coast." * The same author mentions, that in Shetland a granite composed of hornblende, mica, felspar, and quartz graduates in an equally perfect manner into basalt. †

It would be easy to multiply examples to prove that the granitic and trap rocks pass into each other, and are merely different forms which the same elements have assumed, according to the different circumstances under which they have consolidated from a state of fusion. What has been said respecting the mode of explaining the different texture of the central and external parts of the Vesuvian dikes may enable the reader in some measure to comprehend how such differences may originate. ‡

The lavas, which are porous where they have flowed over the crater, and cooled rapidly under comparatively slight pressure, appear compact and porphyritic in the dike. Now these dikes evidently communicate with the crater and the volcanic foci below; so that we may suppose them to be continuous to a vast depth; and the fluid matter below, which cools and consolidates slowly under so enormous a pressure, may be conceived to acquire a very distinct and more crystalline texture, like granite.

If it be objected that we do not find in mountain-

* Syst. of Geol., vol. i. p. 157. † Ibid., p. 158.

‡ See p. 23.

chains volcanic dikes passing upwards into lava, and downwards into granite, we may answer, that our vertical sections are usually of small extent; and if we find in certain places a transition from trap to porous lava, and in others a passage from granite to trap, it is as much as could be expected of this evidence. It should also be remembered, that a large proportion of the igneous rocks, when first formed, cannot be supposed to reach the surface, and these may assume the usual granitic texture without graduating into trap, or into such lava and scoriæ as are found on the flanks of a volcanic cone.

Theory of the origin of granite at all periods. — It is not uncommon for lava streams to require more than ten years to cool in the open air; and where they are of great depth, a much longer period. The melted matter poured from Jorullo, in Mexico, in the year 1759, which accumulated in some places to the height of 550 feet, was found to retain a high temperature half a century after the eruption.* For what immense periods, then, may we not conceive that great masses of subterranean lava in the volcanic foci may remain in a red-hot or incandescent state, and how gradual must be the process of refrigeration! This process may be sometimes retarded for an indefinite period, by the accession of fresh supplies of heat; for we find that the lava in the crater of Stromboli, one of the Lipari islands, has been in a state of constant ebullition for the last two thousand years; and we must suppose this fluid mass to communicate with some cauldron or reservoir of fused matter below. In the Isle of Bourbon, also, where there has been an emission of lava once in

* See Vol. II. p. 187.

every two years for a long period, we may infer that the lava below is permanently in a state of liquefaction.

The great pressure of a superincumbent mass, and exclusion from contact with the atmosphere, and perhaps with the ocean, are some of the conditions which may be necessary to produce the granitic texture; but what I have before said of the causes of volcanic heat operating at considerable depths, will show how complicated may be the processes going on in the interior of the earth, and how different from any within the sphere of our observation at the surface.*

If plutonic rocks, such as granite or porphyry, have originated far below as often as the volcanic have been generated at the surface, it will follow that no small quantity of the former class has been forming in the recent epoch; since we suppose that about two thousand volcanic eruptions may occur in the course of every century, either above the waters of the sea or beneath them.†

We may also infer, that during each preceding period, whether tertiary or secondary, there have been granites and granitiform rocks generated; because we have already discovered the monuments of ancient volcanic eruptions of almost every period.

In the next chapter I shall endeavour to show, that, in consequence of the great depths at which the plutonic rocks usually originate, and of the manner in which they are associated with the older sedimentary strata of each district, it is rarely possible to determine with exactness their relative age. It may be true that the greater portion of them now visible are of higher

* Book ii. chapters 18. and 19. † See Vol. II. p. 224.

antiquity than the oldest secondary strata; and yet they may have been produced in nearly *equal* quantities during *equal periods* of time, from the earliest to the most modern epochs, instead of diminishing in quantity at each successive epoch, as some geologists pretend.

CHAPTER XXVII.

ON THE STRATIFIED ROCKS CALLED "PRIMARY."

Whether any "primary" rocks are truly stratified — Difference between stratification and cleavage — Professor Sedgwick on the Slaty and the Jointed Structure — Alteration of sedimentary strata by dikes (p. 371.) — Manner in which heat may be conveyed through rocks — Conversion of sedimentary into crystalline strata — The term "Hypogene" proposed as a substitute for "primary" (p. 385.)— "Metamorphic" for "stratified primary" rocks — No regular order of succession of hypogene rocks — Cause of the high relative antiquity of visible hypogene formations (p. 390.) — They may have been produced at each successive period in equal quantities — Volume of hypogene rocks supposed to have been formed since the Eocene period — Concluding remarks.

Whether any primary rocks are stratified.— It has been stated that the rocks usually called "Primary," are divisible into the stratified and the unstratified; but some geologists have entertained doubts as to the propriety of applying the term stratified to any rocks of the crystalline or "primary" class. They admit that the latter are often made up of tabular masses, or beds placed one upon the other, something in the manner of true strata; but they deny that the analogy is so perfect as to indicate a similarity of origin: in other words, they do not believe the distinct beds into which crystalline rocks, such as gneiss, mica-schist, and hornblende-schist, are divided, to have been the result of sedimentary deposition from water.

Now it must be conceded that even in rocks which are unequivocally of sedimentary origin, and which contain organic remains, there are many lines of parting that might easily be mistaken for strata, yet which have no connection with stratification. Of these partings some have been distinguished by miners under the name of "joints," others by that of the "planes of cleavage."

Cleavage or slaty structure. — In an admirable essay recently published on this subject, Professor Sedgwick has described the ordinary forms, and speculated on the probable origin, of these different kinds of structure.* His descriptions are derived from an extensive series of original observations, made on the slate rocks of Cumberland and Wales, and will be read by all who are desirous of obtaining a clear and thorough knowledge of this important class of phenomena.

Some of these Cumbrian and Welsh rocks are decidedly of mechanical origin; and some strata contain marine organic remains, so that they must have been deposited from water. But besides being stratified, they are intersected by cleavage planes, which are usually inclined at a very considerable angle to the planes of the strata, and appear to be in no instance exactly coincident with them. In some cases the difference is so small that these planes might easily be supposed parallel; but their inclination to each other in the Welsh chains, is upon an average as much as 30° to 40°. Sometimes the cleavage planes dip towards the same point of the compass as those of stratification, but more frequently they dip to opposite points.

"In that variety of slate which is used for roofing,"

* Geol. Trans., vol. iii. Second Series, p. 461

Professor Sedgwick, "the structure of the rock has been so modified that the traces of its original deposition are quite obliterated; and this remark does not apply merely to single quarries, but sometimes to whole mountains. We can, however, in many slate quarries, and even in hand specimens of slate, discover a number of parallel stripes, sometimes of a lighter, and sometimes of a darker colour than the general mass; and in rocks of the age I am considering, these stripes are universally parallel to the true bedding of the rocks. The proof of this is established by the fact that the assumption leads to consistent results; that these stripes are always parallel to true beds whenever such beds can be discovered, whether by organic remains, by the alternations of dissimilar deposits, or by any other ordinary means. I have seen thousands of examples of the truth of the rule, and not one exception to it among rocks of the age I am considering. Sometimes all these means fail, and we may ramble for miles among mountains of slate without seeing a single trace of their original stratification.

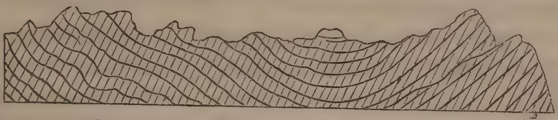
"In examining a formation of greywacké, we may find thick well-defined beds, passing into thin flaggy beds; and these, again, passing into masses, subdivided into very thin laminæ. These thin laminæ often resemble the coarser varieties of slate, and are, indeed, sometimes used for the same purposes. There may, therefore, be cases where, as far as mineral structure is concerned, *slatestones* of cleavage, and *flagstones* (which are layers produced by aqueous deposition), cannot be separated from each other. These cases are, however, very rare exceptions. A *flagstone* is generally distinguished from a true slate by slight deviations in its plane; occasionally by what is called the

ripple mark; by a dull granular surface; by scattered flakes of mica, entirely unlike the continuous chloritic flakes of a true cleavage; and sometimes by organic remains studded on its surface. By such indications as these, and by the undefinable power acquired by habit, a Welsh quarry-man, accustomed to work in the upper division of the schistose groups, seldom fails to separate the laminæ of deposition from true slates; and in the same quarry he will point out the distinction between the planes of stratification and the planes of cleavage.

"I think it obvious," continues the same author, "that the contortions of slate rocks are phenomena quite distinct from cleavage, and that the curves presented by such formations are the true lines of disturbed strata." *

In the accompanying section, given by the Professor

Fig. 161.



Parallel planes of cleavage intersecting curved strata.

to illustrate these appearances in the Welsh slate rocks, we see the cleavage planes preserving an almost geometrical parallelism, while they pass through contorted strata of "hard greenish slate, obviously of sedimentary origin." A region more than thirty miles in length, and eight to ten in breadth, exhibits this structure on a magnificent scale. Many of the contorted strata "are of a coarse mechanical structure; but subordinate to them are fine, crystalline, chloritic slates. But the coarser beds and the finer, the twisted and the straight,

* Sedgwick, Geol. Trans., vol. iii. Second Series, p. 474.

have all been subjected to one change. Crystalline forces have re-arranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata. And again, through all this region, whatever be the contortions of the rocks the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining at a great angle to a point only a few degrees west of magnetic north.

"Without considering the crystalline flakes along the planes of cleavage, which prove that crystalline action has modified the whole mass, we may affirm that no retreat of parts, no contraction in dimensions in passing to a solid state, can explain such phenomena as these. They appear to me only resolvable on the supposition that crystalline or polar forces acted on the whole mass simultaneously, in given directions, and with adequate power.

"There is at first sight a difficulty in comprehending the vastness of those forces, which nature must have applied in producing such effects. But difficulties of this kind are little thought of, if we can resolve them into any known mode of material action. Now, in crystallization, there is something like a definite polarity in each particle, by which it is compelled to turn in a given direction, and group itself with other particles in definite forms; and if this modification of internal structure be carried on through a very large mass of matter, is it not probable that there is an accumulated intensity of crystalline action in each part, so that the whole intensity of crystalline force modifying the mass is not equal to the sum of the forces necessary to crystallize each part independently, but is some function of that sum, whereby it may be in-

creased almost indefinitely? I see nothing improbable in this kind of accumulated attraction, and it will explain many geological phenomena." *

"As the effects," he continues, "which have been produced through spaces of great extent are nearly uniform, the crystalline forces must have been nearly uniform, at least as to certain directions, which seems to imply a certain degree of homogeneity in the masses acted on; and, as a matter of fact, where the slaty cleavage is very perfectly brought out, the structure of the rock always makes an approach to homogeneity. Where the quartzose beds of coarse greywacké abound very much, the cleavage is seldom very perfect, or is at least confined to particular strata."†

Jointed structure. — "Besides the planes of cleavage," observes Professor Sedgwick, "we often find in large slate quarries one or more sets of cross joints, which, combined with cleavage, divide the rock into rhombohedral solids. These solids are not capable of indefinite subdivision into similar solids, except in one direction, namely, that of true cleavage; and in this way, even in hand specimens, we may generally distinguish the true cleavage planes from the joints. These last are fissures placed at definite distances from each other, the masses of rock between them having, generally speaking, no tendency to cleave in a direction parallel to them. Such a structure seems in most cases to have been produced mechanically, either by a strain upon the rock from external force, producing more or less regular sets of cracks and fissures, or by a mechanical tension on the mass, produced probably

* Sedgwick, Geol. Trans., vol iii. Second Series, pp. 477, 478.

† Sedgwick, ibid., p. 478.

by contraction, during its passage from a fluid, or semi-fluid, into a solid state. Cleavage planes are, on the contrary, the results of the ultimate chemical arrangement of the particles of a rock, and appear in most cases to be unconnected with any direct mechanical action.

"A slaty and joined structure are, however, often exhibited together; and cases may arise where it is almost impossible to decide whether a certain set of fissures are to be called joints, or cleavage planes: but difficulties of this kind are the exception, and not the rule." *

The jointed structure is common both to the stratified and unstratified rocks; but is best seen in the unstratified, as in granite, or columnar basalt. In the Swiss and Savoy Alps, Mr. Bakewell has well remarked that enormous masses of limestone are cut through so regularly by nearly-vertical partings, and these are often so much more conspicuous than the seams of stratification, that an unexperienced observer will almost inevitably confound them, and suppose the strata to be perpendicular when in fact they are almost horizontal.†

The cause of this tendency to a jointed structure is by no means understood; but it appears, from recent observations, that ice sometimes presents a similar arrangement of parts. Scoresby, indeed, when speaking of the icebergs of Spitzbergen, had long ago stated, "that they are full of rents, extending perpendicularly downwards, and dividing them into innumerable columns." Colonel Jackson has lately investigated this subject more attentively, and has found that the ice

* Sedgwick, Geol. Trans., vol. iii. Second Series, pp. 480, 481.

† Introduction to Geology, chap. iv.

on the Neva, at St. Petersburg, at the beginning of a thaw, when two feet in thickness, is traversed by rows of very minute air-bubbles extending in straight lines, sometimes a little inflected, from the upper surface of the ice towards the lower, within from two to five inches of which they terminate. "Other blocks presented these bubbles united, so as to form cylindrical canals, a little thicker than a horse-hair. Observing still further," he says, "I found blocks in which the process was more advanced, and two, three, or more clefts, struck off in different directions from the vertical veins, so that a section perpendicular to the vein would represent in miniature the star-formed cracks of timber. Finally, in some pieces, these cracks united from top to bottom of the veins, separating the whole mass into vertical prisms, having a greater or less number of sides. In this state a slight shock was sufficient to detach them; and the block with its scattered fragments was in all respects the exact miniature resemblance, in crystal, of a Giant's Causeway. The surface was like a tessellated pavement, and the columns rose close, adhering and parallel, from the compact mass of a few inches at the under surface. More or less time is required for the process, which I have since seen in all its different stages." *

Stratification of granitic schists.—If we examine gneiss, which consists of the same materials as granite or mica-schist, which is a compound of quartz and mica, or hornblende schist, which is formed of hornblende and felspar, or any other member of the so-called primary division, we find that they are each made up of a succes-

* Journ. of Roy. Geogr. Soc., vol. v. p. 19.

sion of beds, the planes of which are, to a certain extent, parallel to each other in a manner analogous to that exhibited by sedimentary formations of all ages. They may occasionally exhibit, in addition, both a jointed and a slaty structure; but they are also divided into uneven foliated layers, or in some cases into thick beds which resemble strata of deposition.

The resemblance to stratification in the granitic schists often extends very far; for the beds are occasionally contorted, or they are made up of laminæ placed diagonally, as in many sedimentary formations before described *, such laminæ not being regularly parallel like the planes of cleavage.

This disposition of the layers is illustrated in the accompanying diagram, in which I have represented

Fig. 162.

Lamination of clay-slate, Montagne de Seguinat, near Gavarnie, in the Pyrenees.

carefully the stratification of a coarse argillaceous schist, which I examined in the Pyrenees, part of which approaches in character to a green and blue roofing slate, while part is extremely quartzose, the whole mass passing downwards into micaceous schist. The vertical section here exhibited is about three feet in height, and the layers are sometimes so thin that

* See above, p. 91.

fifty may be counted in the thickness of an inch. Some of them consist of pure quartz.

Another striking point of analogy between the stratification of the crystalline formations and that of the secondary and tertiary periods, is the alternation, in each, of beds varying greatly in composition, colour, and thickness. We observe, for instance, gneiss alternating with layers of black hornblende-schist, or with granular quartz or limestone; and the interchange of these different strata may be repeated for an indefinite number of times. In like manner, mica-schist alternates with chlorite-schist, and with granular limestone in thin layers.

As we observe in the secondary and tertiary formations strata of pure siliceous sand alternating with micaceous sand and with layers of clay, so in the "primary" we have beds of pure quartz rock alternating with mica-schist and clay-slate. As in the secondary and tertiary series we meet with limestone alternating again and again with micaceous or argillaceous sand, so we find in the "primary" gneiss and mica-schist alternating with pure and impure granular limestones.

Passage of gneiss into granite.—But if we attribute the stratification of gneiss, mica-schist, and other associated rocks, to sedimentary deposition from a fluid, we encounter this difficulty, that there is often a transition from gneiss, a member of the stratified and therefore sedimentary series, into granite, which, as I have shown, is of igneous origin. Gneiss is composed of the same ingredients as granite, and its texture is equally crystalline. It sometimes occurs in thick beds, and in these the rock is often quite undistinguishable, in hand specimens, from granite; yet the lines of

stratification are still evident. These lines, it is conceived, imply deposition from water; while the passage into granite would lead us to infer an igneous origin. In what manner, then, can these apparently conflicting views be reconciled? The Huttonian hypothesis offers, I think, the only satisfactory solution of this problem. According to that theory, the materials of gneiss were originally deposited from water in the usual form of aqueous strata; but these strata were subsequently altered by subterranean heat, so as to assume a new texture. The reader will be in some degree prepared, by what has been stated in the preceding pages, to conclude, that when voluminous masses of melted and incandescent rock, accompanied by intensely heated gases under great pressure, have been for ages in contact with sedimentary deposits, they may produce great alterations in their texture; and this alteration may admit of every intermediate gradation between that resulting from perfect fusion and the slightest modification which heat can produce.

Some light has been thrown on the changes which stratified masses may undergo subsequently to their original deposition by direct experiment on the fusion of rocks in the laboratory, and still more by observations on strata in contact with igneous veins and dikes. In studying the latter class of phenomena, we have the advantage of examining the condition of the same continuous rock at some distance from the dike, where it has escaped the influence of heat, and its state where it has been near to, or in contact with, the fused mass. The changes thus exhibited may be regarded as the results of a series of experiments, made by nature on a greater scale than we can imitate, and under every variety of condition, in respect to the mineral ingredi-

ents acted upon, the intensity of heat or pressure, and the celerity or slowness of the cooling process.

Strata altered by volcanic dikes — Plass Newydd.— One of the most interesting examples of alteration in the proximity of a volcanic dike occurs near Plas Newydd, in Anglesea, described by Professor Henslow. The dike is 134 feet wide, and consists of basalt (dolerite of some authors), a compound of felspar and augite. Strata of shale and argillaceous limestone, through which it cuts perpendicularly, are altered to a distance of thirty, or even, in some places, to thirty-five feet from the edge of the dike. The shale, as it approaches the basalt, becomes gradually more compact, and is most indurated where nearest the junction. Here it loses part of its schistose structure, but the separation into parallel layers is still discernible. In several places the shale is converted into hard porcellanous jasper. In the most hardened part of the mass the fossil shells, principally *Productæ*, are nearly obliterated; yet even here their impressions may frequently be traced. The argillaceous limestone undergoes analogous mutations, losing its earthy texture as it approaches the dike, and becoming granular and crystalline. But the most extraordinary phenomenon is the appearance in the shale of numerous crystals of analcime and garnet, which are distinctly confined to those portions of the rock affected by the dike.* Garnets have been observed, under very analogous circumstances, in High Teesdale, by Professor Sedgwick, where they also occur in shale and limestone altered by a basaltic dike. This discovery is most interesting, because garnets often abound in mica-schist; and we

* Trans. of Cambridge Phil. Soc., vol. i. p. 406.

see in the instance above cited that they did not previously exist in the shale and limestone, but have evidently been produced by heat or heated gases in rocks in which the marks of stratification have not been effaced.

Stirling Castle. — To select another example of alteration by dikes: the rock of Stirling Castle is a calcareous sandstone, fractured and forcibly displaced by a mass of green-stone, which has evidently invaded the strata in a melted state. The sandstone has been indurated, and has assumed a texture approaching to hornstone near the junction. So also in Arthur's Seat and Salisbury Craig, near Edinburgh, a sandstone is seen to come in contact with green-stone, and to be converted into a jaspideous rock.*

Antrim. — In several parts of the county of Antrim, in the north of Ireland, chalk with flints is traversed by basaltic dikes. The chalk is there converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dike, being greatest near the point of contact, and thence gradually decreasing till it becomes evanescent. "The extreme effect," says Dr. Berger, "presents a dark brown crystalline limestone, the crystals running in flakes as large as those of coarse *primitive* limestone; the next state is saccharine, then fine-grained and arenaceous; a compact variety, having a porcellanous aspect and a bluish-grey colour, succeeds: this, towards the outer edge, becomes yellowish white, and insensibly graduates into the unaltered chalk. The flints in the altered chalk usually assume a grey yellowish

* Illust. of Hutt. Theory, §§ 253 and 261. Dr. Macculloch, Geol. Trans., First Series, vol. ii. p. 305.

colour." * All traces of organic remains are effaced in that part of the limestone which is most crystalline.

As the carbonic acid has not been expelled, in this instance, from that part of the rock which must be supposed to have been melted, the change probably took place under considerable pressure; for Sir James Hall proved, that, under ordinary circumstances, it would require the weight of about 1700 feet of sea-water, which would be equivalent to the pressure of a column of liquid lava about 600 feet high, to prevent this acid from being given off. The experiments of Faraday have recently shown that, if carbonate of lime be perfectly dry, it may be melted under a very slight pressure, without the carbonic acid assuming a gaseous form; but it is probable that in the earth's crust calcareous rocks are rarely, if ever, entirely free from moisture.

Another of the dikes of the north-east of Ireland has converted a mass of red-sandstone into hornstone. † By another, the slate-clay of the coal-measures has been indurated, and has assumed the character of flinty slate ‡; and in another place the slate-clay of the lias has been changed into flinty slate, which still retains numerous impressions of ammonites. § One of the green-stone dikes of the same country passes through a bed of coal, which it reduces to a cinder for the space of nine feet on each side. ‖ Yet there are places in the north of Ireland, where the chalk is scarcely, if at

* Dr. Berger, Geol. Trans., First Series, vol. iii. p. 172.

† Rev. W. Conybeare, Geol. Trans., First Series, vol. iii. p. 201.

‡ Ibid., p. 205.

§ Ibid., p. 213.; and Playfair, Illust. of Hutt. Theory, § 253.

‖ Ibid., p. 206.

all, altered by the contact of basaltic dikes, and a similar phenomenon is not unfrequent in other districts, at the junction of trap with different kinds of strata. This great inequality in the effects of the igneous rocks may often arise from an original difference in their temperature and in that of the entangled gases, such as is ascertained to prevail in different lavas, or in the same lava near its source and at a distance from it. The power also of the invaded rocks to conduct heat may vary according to their composition, structure, and the fractures which they may have experienced, and, perhaps, as I shall hint in the sequel, the quantity of steam or hot water they contain. It should also be borne in mind that in some cases the melted rock may begin to cool from the first; whereas, in other cases, although parting constantly with its heat, it may receive fresh accessions of caloric from below.

The secondary sandstones in Sky are converted into solid quartz in several places where they come in contact with veins or masses of trap; and a bed of quartz, says Dr. Macculloch, has been found near a mass of trap, among the coal-strata of Fife, which was in all probability a stratum of ordinary sandstone subsequently indurated by the action of heat.*

Alterations of strata in contact with granite.—Having selected these from innumerable examples of changes produced by volcanic dikes, we may next consider those caused by the contiguity of plutonic rocks. To some of these I have already adverted, when speaking of granite veins, and endeavouring to establish the igneous origin of granite. It was stated that the main body of the Cornish granite sends forth veins through

* Syst. of Geol., vol. i. p. 206.

the killas of that country *, — a coarse argillaceous schist, which is converted into hornblende-schist near the contact with the veins. These appearances are well seen at the junction of the granite and killas in St. Michael's Mount, a small island nearly 300 feet high, situated in the bay, at a distance of about three miles from Penzance.

The granite, says Mr. De la Beche, of Dartmoor, in Devonshire, has intruded itself into the greywacké, twisting and contorting the strata, and sending veins into them. Hence some of the slate rocks have become "micaceous, others more indurated, and with the characters of mica-slate and gneiss, while others again appear converted into a hard-zoned rock strongly impregnated with felspar." †

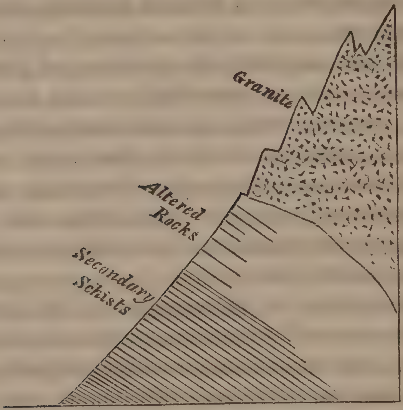
We learn from the investigations of M. Dufrénoy, that in the eastern Pyrenees there are mountain masses of granite posterior in date to the lias and chalk of that district, and that these secondary rocks are greatly altered in texture, and often charged with iron ore, in the neighbourhood of the granite. Thus in the environs of St. Martin, near St. Paul de Fénouillet, the the chalky limestone becomes more crystalline and saccharoid as it approaches the granite, and loses all traces of the fossils which it previously contained in abundance. At some points also it becomes dolomitic, and filled with small veins of carbonate of iron, and spots of red iron-ore. At Rancié the lias nearest the granite is not only filled with iron-ore, but charged with pyrites, tremolite, garnet, and a new mineral somewhat allied to felspar, called, from the place in the Pyrenees where it occurs, "couzeranite."

* See diagram, Fig. 159.

† Geol. Manual, p. 479.

In the department of the Hautes Alpes, in France, near Vizille, M. Elie de Beaumont traced a black argillaceous limestone, charged with belemnites, to within a few yards of a mass of granite. Here the

Fig. 163.



Junction of granite with Jurassic or oolite strata in the Alps, near Champoleon.

limestone begins to put on a granular texture, but is extremely fine-grained. When nearer the junction, it becomes grey and has a saccharoid structure. In another locality, near Champoleon, a granite composed of quartz, black mica, and rose-coloured felspar, is observed partly to overlie the secondary rocks, producing an alteration which extends for about thirty feet downwards, diminishing in the beds which lie farthest from the granite. (See Fig. 163.) In the altered mass the argillaceous beds are hardened, the limestone is saccharoid, the grits quartzose, and in the midst of them is a thin layer of an imperfect granite. It is also an important circumstance, that near the point of contact, both the granite and the secondary

rocks become metaliferous, and contain nests and small veins of blende, galena, iron, and copper pyrites. The stratified rocks become harder and more crystalline, but the granite, on the contrary, softer and less perfectly crystallized near the junction.*

It will appear from sections in the Alps, described by M. Hugi, that some of the secondary beds of limestone and slate, which are in a similar manner overlaid by granite, have been altered into gneiss and mica-schist.† Some of these altered sedimentary formations are supposed, by M. Elie de Beaumont, to be of the age of the lias of England, and others to be even as modern as the Jurassic or oolite formations.

We can scarcely doubt, in these cases, that the heat communicated by the granitic mass, accompanied, perhaps, by gases at a high temperature, have reduced the contiguous strata to semifusion, and that, on cooling slowly, the rock assumed a crystalline texture. The experiments of Gregory Watt prove, distinctly, that a rock need not be perfectly melted in order that a re-arrangement of its component particles should take place, and that a more crystalline texture should ensue.‡ We may easily suppose, therefore, that all traces of shells and other organic remains may be destroyed, and that new chemical combinations may arise, without the mass being so fused as that the lines of stratification should be wholly obliterated.

In allusion to the passage from granite to gneiss, above described §, Dr. Macculloch remarks, that, "in numerous parts of Scotland, where the leading masses

* Elie de Beaumont, sur les Montagnes de l'Oisans, &c., Mém. de la Soc. d'Hist. Nat. de Paris, tome v.

† Natur. Historische Alpenreise, Soleure, 1830.

‡ Phil. Trans., 1804. § See p. 369.

of gneiss are schistose, evenly stratified, and scarcely ever traversed by granite veins, they become contorted and irregular as they approach the granite; assuming also the granitic character, and becoming intersected by veins, numerous in proportion to the vicinity of the mass. The conclusion," he adds, "is obvious; the fluid granite has invaded the aqueous stratum as far as its influence could reach, and thus far has filled it with veins, disturbed its regularity, and generated in it a new mineral character, often absolutely confounded with its own. And if the more remote beds, and those alternating with other rocks, are not thus affected, it is not only that it has acted less on those; but that, if it had equally affected them, they never could have existed, or would have been all granitic and venous gneiss." *

It should, however, be understood, that the alterations caused by volcanic dikes, granite veins, and even large masses of granite, can only afford us some analogy to those which have given rise to the metamorphic structure; for, according to the views explained in the second book (chaps. 18 and 19.), volcanic heat itself may be derived from chemical and electrical action pervading large portions of the earth's crust. This action, which, when most intense, may reduce the elements of rocks to fusion, and give rise to the most perfect granitic structure, may perhaps, when less energetic, give rise to a crystalline texture, without destroying stratification.

As to the degree of heat required to superinduce such changes, it must, in the present state of science, be matter of conjecture; but some geologists object to

* Syst. of Geol., vol. ii. p.145.

the metamorphic theory, on the ground that rocks are extremely bad conductors of heat. Now it is worthy of consideration, how far heat, instead of being conducted through the solid parts of rocks, may be carried by heated gases through their pores; for we have seen that volcanic eruptions are attended by the evolution of steam and other gases, which rush out in enormous volume, and at a high temperature, for days, weeks, or years continuously, and which are given off by lava even after it has begun to assume a solid form. These aëriform fluids, if unable to force their way into the atmosphere, may, nevertheless, when brought into contact with rocks, pass through their pores. According to the experiments of Henry, water, under an hydrostatic pressure of ninety-six feet, will absorb three times as much carbonic acid gas as it can under the ordinary pressure of the atmosphere. Although this increased power of absorption would be diminished, in consequence of the higher temperature found to exist as we descend in the earth, yet Professor Bischoff has shown that the heat by no means augments in such a proportion as to counteract the effect of augmented pressure.* There are other gases, as well as the carbonic acid, which water absorbs, and more rapidly in proportion to the amount of pressure. Now even the most compact rocks may be regarded, before they have been exposed to the air and dried, in the light of sponges filled with water; and it is conceivable that heated gases, brought into contact with them, at great depths, may be absorbed readily, and transfused through their pores. Although the gaseous matter first absorbed would soon be con-

* Poggendorf's Annalen, No. XVI. Second Series, vol. iii.

densed, and part with its heat, yet the continued arrival of fresh supplies from below, might, in the course of ages, cause the temperature of the water, and with it that of the containing rock, to be materially raised.

M. Fournet, in his description of the metaliferous gneiss near Clermont, in Auvergne, states that all the minute fissures of the rock are quite saturated with free carbonic acid gas, which rises plentifully from the soil there and in many parts of the surrounding country. The various elements of the gneiss, with the exception of the quartz, are all softened; and new combinations of the acid, with lime, iron, and manganese, are continually in progress.*

Another illustration of the power of subterranean gases is afforded by the stufas of St. Calogero, situated in the largest of the Lipari Islands. Here, according to the description lately published by Hoffmann, horizontal strata of tuff, extending for four miles along the coast, and forming cliffs more than 200 feet high, have been discoloured in various places, and strangely altered by the "all-penetrating vapours." Dark clays have become yellow, or oftn snow-white; or have assumed a chequered and brecciated appearance, being crossed with ferruginous red stripes. In some places the fumeroles have been found by analysis to consist partly of sublimations of oxide of iron; but it also appears that veins of calcedony and opal, and others of fibrous gypsum, have resulted from these volcanic exhalations.†

I have before referred to M. Virlet's account of the corrosion of hard, flinty, and jaspideous rocks, near

* See Vol. I. p. 327.

† Hoffmann's Liparischen Inseln, p. 38. Leipzig, 1832.

Corinth, by the prolonged agency of subterranean gases*; and to Dr. Daubeny's description of the decomposition of trachytic rocks in the Solfatara, near Naples, by sulphuretted hydrogen and muriatic acid gases.†

Although in all these instances we can only study the phenomena as exhibited at the surface, it is clear that the gaseous fluids must have made their way through the whole thickness of porous or fissured rocks, which intervene between the subterranean reservoirs of gas and the external air. The extent therefore of the earth's crust, which the vapours have permeated and are now permeating, may be thousands of fathoms in thickness, and their heating and modifying influence may be spread throughout the whole of this solid mass.

The study of metaliferous veins also, especially those which are admitted to be fissures filled from below, is calculated to throw light on the manner in which heated vapours and aqueous solutions may find their way up through the interstices of rocks, raising their temperature, and sometimes transfusing into them new mineral substances. A great number of these fissures have evidently been filled in the first instance with rubbish, resulting from fragments of the adjoining rocks; and through this rubbish various siliceous, calcareous, and metallic vapours or solutions appear to have risen, causing precipitates of quartz, hornstone, calcareous spar, lead, zinc, and other metals, often perfectly distinct in their composition from any of the elements of the rocks which form the walls of such

* See Vol. III. p. 225.; and Bulletin de la Soc. Géol. de France, tom. ii. p. 330.

† See Vol. II. p. 143.; and Daubeny's Volcanos, p. 167.

fissures. Proofs are not wanting that these rents have been caused and filled at different epochs. Thus, for example, some of the silver and cobalt veins in Bohemia appear, from the observations of Mayer and Fournet, to be of the age of the chalk *, while other metaliferous veins, in the same district, were contemporaneous with a tertiary basalt.† M. Necker has also shown that a relation exists between the position of numerous metallic veins in various countries and subjacent masses of plutonic rock; so that the emanations rising from such igneous masses may, in many instances, have given rise to the more crystalline substances, whether metallic or not, which constitute the contents of the veins.

If after more fully reflecting upon those various causes of change in the composition and structure of rocks, which have only been glanced at in the above sketch, the reader conceives the possibility of a very great amount of alteration being induced in the course of time, he may be prepared to conjecture that gneiss and mica-schist may be nothing more than altered micaceous and argillaceous sandstones, and that granular quartz may have been derived from siliceous sandstone, and compact quartz from the same materials. Clay-slate may be altered shale, and shale appears to be clay which has been subjected to great pressure. Granular marble has probably originated in the form of ordinary limestone, having in many instances been replete with shells and corals now obliterated, while calcareous sands and marls have been changed into impure crystalline limestones.

* D'Aubuisson, Traité de Géog., tom. iii. p. 497.

† Ibid., p. 508.

"Hornblende-schist," says Dr. Macculloch, "may at first have been mere clay; for clay or shale is found altered by trap into Lydian stone, a substance differing from hornblende-schist almost solely in compactness and uniformity of texture." * "In Shetland," remarks the same author, "argillaceous-schist (or clay-slate), when in contact with granite, is sometimes converted into hornblende-schist, the schist becoming first siliceous, and ultimately, at the contact, hornblende-schist." †

Associated with the rocks termed primary, we meet with anthracite, just as we find beds of coal in sedimentary formations; and we know that, in the vicinity of some trap dikes, coal is converted into anthracite.

This theory, if confirmed by observation and experiment, may enable us to account for the high position in the series usually held by clay-slate relatively to hornblende-schist, as also to gneiss and mica-schist, which so commonly alternate with hornblende-schist; for we must suppose the heat which alters the strata to proceed, in almost all cases, from below upwards, and to act with greatest intensity on the inferior strata. If, therefore, several sets of argillaceous strata or shales be superimposed upon each other in a vertical series of beds in the same district, the lowest of these will be converted into hornblende-schist, while the uppermost may continue in the condition of clay-slate.

It has been objected that the chemical composition of the secondary strata differs essentially from that of the crystalline schists into which they are supposed to be convertible. ‡ The "primary" schists, it is said,

* Syst of Geol., vol. i. p. 210. † Ibid., p. 211.

‡ Dr. Boase, Primary Geology, p. 319.

usually contain a considerable proportion of potash or of soda, which the secondary clays, shales and slates do not, these last being the result of the decomposition of felspathic rocks, from which the alkaline matter has been abstracted during the process of decomposition. But this reasoning proceeds on insufficient and apparently mistaken data; for a large portion of what is usually called clay, marl, shale, and slate does actually contain a certain and often a considerable proportion of alkali; so that it is difficult in many countries to obtain clay or shale sufficiently free from alkaline ingredients to allow of their being burnt into bricks or used for pottery.

Thus the argillaceous shales, as they are called, and slates of the old red-sandstone, in Forfarshire and other parts of Scotland, are so much charged with alkali, derived from triturated felspar, that instead of hardening when exposed to fire, they melt readily into a glass. They appear to consist of extremely minute grains of the various ingredients of granite, which are distinctly visible in the coarser-grained varieties, and in almost all the interposed sandstones. These laminated clays, marls, and shales might certainly, if crystallized, resemble in composition many of the primary strata.

Another objection to the metamorphic theory has been derived from the alternation of highly crystalline strata with others having a less crystalline texture. The heat, it is said, in its ascent from below must have traversed the less altered schists before it reached a higher and more crystalline bed. In answer to this, it may be observed, that if a number of strata differing greatly in composition from each other be subjected to equal quantities of heat, there is every

probability that some will be more fusible than others. Some, for example, will contain soda, potash, lime, or some other ingredient capable of acting as a flux; while others may be destitute of the same elements, and so refractory as to be very slightly affected by a degree of heat capable of reducing others to semi-fusion. Nor should it be forgotten that, as a general rule, the less crystalline rocks do really occur in the upper, and the more crystalline in the lower part of each metamorphic series.

To some it appears a phenomenon very difficult of explanation, that detached masses of granite, and even layers of it, should often occur in the midst of strata, near their contact with granite. This appearance of isolation is usually deceptive, arising from the intersection in a vertical precipice of tortuous veins of granite, as Professor Henslow has shown to be the case in several places in the cliffs of Anglesea.* I may also remark, that if unaltered sedimentary strata contained here and there layers or nests of the ingredients of granite, the rest of the mass consisting of different materials, and if the temperature of the whole has been sufficiently raised by plutonic action, the result might be, that nodules and threads of granite might be formed in certain spots only.

The term "Hypogene" proposed instead of Primary.—It will appear from the reasoning explained in this and the preceding chapter, that the popular nomenclature of Geology, in reference to the rocks called "primary," is not only imperfect, but in a great degree founded on a false theory; inasmuch as some granites and granitic schists are of origin posterior to many

* Camb. Trans., vol. i.

secondary rocks. In other words, some *primary* formations can already be shown to be newer than many *secondary* groups—a manifest contradiction in terms.

Yet granite and gneiss, and the families of stratified and unstratified rocks connected with each of them, belong to one great natural division of mineral masses having certain characters in common; and it is therefore convenient that the class to which they belong should receive some common name—a name which must not be of chronological import, and must express on the one hand, some peculiarity equally attributable to granite and gneiss (to the plutonic as well as the *altered* rocks), and which, on the other, must have reference to characters in which those rocks differ, both from the volcanic and from the *unaltered* sedimentary strata. I propose the term "hypogene" for this purpose, derived from ὑπο, *subter*, and γινομαι, *nascor;* a word implying the theory that granite and gneiss are both *nether-formed* rocks, or rocks which have not assumed their present form and structure at the surface. It is true that gneiss and all stratified rocks must have been deposited originally at the surface, or on that part of the surface of the globe which is covered by water; but, according to the views explained in this and the foregoing chapter, they could never have acquired their crystalline texture, unless acted upon by heat and chemical forces under pressure in those regions, and under those circumstances where the plutonic rocks are generated.

The term "Metamorphic" proposed for stratified primary.—We may divide the hypogene rocks, then, into the unstratified, or plutonic, and the *altered* stratified. For these last the term "metamorphic" (from μετα, *trans*, μορφη, *forma*,) may be used. The last-

mentioned name need not, however, be often resorted to, because we may speak of hypogene *strata*, hypogene *limestone*, hypogene *schist;* and this appellation will suffice to distinguish the formations so designated from the plutonic rocks. By referring to the table (No. II. p. 402.), the reader will see the chronological relation which I conceive the two classes of hypogene rocks to bear to the strata of different ages.

No order of succession in hypogene formations. — When we regard the tertiary and secondary formations simply as mineral masses uncharacterized by organic remains, we perceive an indefinite series of beds of limestone, clay, marl, siliceous sand, sandstone, coal, and other materials, alternating again and again without any fixed or determinate order of position. The same may be said of the hypogene formations; for in these a similar want of arrangement is manifest, if we compare those occurring in different countries. Gneiss, mica-schist, hornblende-schist, quartz rock, hypogene limestone, and the rest, have no invariable order of superposition, although, for reasons above explained, clay-slate must usually hold a superior position relatively to hornblende-schist.

I do not deny that, in a particular mountain-chain, a chronological succession of hypogene formations may be recognized, for the same reason that in a country of limited extent there is an order of position in the secondary and tertiary rocks, limestone predominating in one part of the series, clay in another, siliceous sand in a third, and so of other compounds. It is probable that a similar prevalence of a regular order of arrangement in the hypogene series throughout certain districts led the earlier geologists into a belief that they should be able to fix a definite order of succession

for the various members of this great class throughout the world.

That expectation has certainly not been realized; yet was it more reasonable than the doctrine of the universality of particular kinds of rock which were admitted to be of sedimentary origin; for there is undoubtedly a remarkable identity in the mineral character of the hypogene formations, both stratified and unstratified, in all countries; although the notion of a uniform order of succession in the different groups must be abandoned.

The student may, perhaps, object to the views above given of the relation of the sedimentary and metamorphic rocks, on the ground that there is frequently, indeed usually, an abrupt passage from one to the other. This phenomenon, however, admits of the same explanation as the fact that the beds of lakes and seas are now frequently composed of hypogene rocks. In these localities the hypogene formations have been brought up near to the surface, and laid bare by denudation. New sedimentary strata are thrown down upon them, and in this manner the two classes of rocks, the aqueous and the hypogene, come into immediate contact, without any gradation from one to the other. As we suppose the plutonic and metamorphic rocks to have been uplifted at all periods in the earth's history, so as to have formed the bottom of the ocean and of lakes, by the same operations which have carried up marine strata to the summits of lofty mountains, we must suppose the juxtaposition of the two great orders of rocks, now alluded to, to have been a necessary result of all former revolutions of the globe.

But occasionally a transition is observable from strata containing shells, and displaying an evident mechanical

structure, to others which are partially altered; and from these again we sometimes pass insensibly into the hypogene series. Some of the argillaceous schists in Cornwall are of this description, being undistinguishable from the hypogene schists of many countries, and yet exhibiting, in a few spots, faint traces of organic remains. In parts of Germany, also, there are schists which, from their chemical condition, must be called metamorphic; yet which are interstratified with greywacké, a rock probably modified by heat, but which contains casts of shells, and often displays unequivocal marks of being an aggregate of fragments of pre-existing rocks.

The same observation holds true in respect to the Cumbrian and Welsh slate rocks before alluded to as described by Professor Sedgwick.* They are metamorphic slates alternating with a few mechanical and fossiliferous beds. If it be asked by what characters we can draw the line and determine where the metamorphic series ends, and the sedimentary begins, I reply that, if this be difficult or impossible, it only strengthens the argument adduced in the preceding part of this chapter; for, according to the theory proposed, we must expect to find strata in every intermediate condition between the most and the least altered.

Had Werner's term "transition" been restricted exclusively to certain peculiarities of mineral structure, and never connected with the presence of particular species of fossils, in consequence of which it soon acquired a chronological import, that term might have been conveniently retained to designate an intermediate condition of strata when they exhibit

* See p. 361.

the characters of rocks of the metamorphic series with occasional traces of a mechanical structure and organic remains.

Some geologists, who shrink from the theory that all the hypogene strata, beautifully compact and crystalline as they are, have once been in the state of ordinary mud, clay, marl, sand, gravel, and limestone, such as are now forming beneath the waters, resort, in their desire to escape from such conclusions, to the hypothesis, that *chemical causes* once acted with intense energy, and that by their influence purely crystalline strata were precipitated; a theory which to me appears as mysterious and unphilosophical as the doctrine of a "plastic virtue," introduced by the earlier writers to explain the origin of fossil-shells and bones.

Relative age of the visible hypogene rocks. — It was stated, at the close of the last chapter, that a great portion of the plutonic rocks now visible are of higher antiquity than the oldest secondary strata; the same may be said of the stratified hypogene formations, which are therefore entitled to the appellation of primary, in the strict sense of the word, as anterior in age to the greywacké, or oldest known fossiliferous group. But we can, in some instances, demonstrate that there are granites of posterior origin to certain secondary strata, and that *secondary* strata have been converted into the *metamorphic*. Examples of such phenomena are rare, and their rarity is quite consistent with the theory, that the hypogene formations, both stratified and unstratified, may have been always generated in nearly equal quantities during periods of equal duration.

I conceive that the granite and gneiss of periods more recent than the carboniferous and greywacké formations are still, for the most part, concealed; and

those portions which are visible can rarely be shown, by geological evidence, to have originated during secondary periods. It is very possible, for example, that considerable tracts of hypogene strata in the Alps may be altered oolite, altered lias, or altered secondary rocks inferior to the lias; but we can scarcely ever hope to substantiate the fact, because, whenever the change of texture is complete, no characters remain to afford us any insight into the probable age of the mass. Where granite happens to have intruded itself in such a manner as partially to overlie a mass of lias or other strata, as in the case before alluded to (Fig. 163., p. 376.), we may prove that *fossiliferous* strata have been converted into gneiss, mica-schist, clay-slate, or granular marble; but if the action of the heat upon the strata had been more intense, these inferences could not have been drawn; and it might then have been supposed that no alpine hypogene strata were newer than the oldest secondary rocks.

Considerable difficulty and misapprehension, in regard to the antiquity of the metamorphic rocks, may arise from the circumstance of their having been deposited at one period, and having assumed their crystalline texture at another. Thus, for example, if an Eocene granite should invade the lias, and superinduce a hypogene structure, to what period shall we refer the altered strata? Shall we say that they are metamorphic rocks of the Eocene or Liassic eras? They assumed their stratified form when the animals and plants of the lias flourished; they have become metamorphic during the Eocene period. It would be preferable, in such instances, I think, to consider them as hypogene strata of the Eocene period, or of that in which they were altered; yet it would rarely be possible to esta-

blish their true age. For this purpose we ought to know the granite, to which the change of texture was due, to be newer than the lias which it penetrated; but there would rarely be any data to show that this granite might not have been injected at the close of the Liassic period, or at some much later era.

The metamorphic rocks must in all cases be the oldest, that is to say, they must lie at the bottom of each series of superimposed strata; but the hypogene strata of one country may be, and frequently are, of a very different age from those of another. The greater part, however, of the visible hypogene rocks are, probably, more ancient than the oldest fossiliferous formations. In the latter, we frequently discover pebbles of hypogene rocks, namely, granite, gneiss, mica-schist, and clay-slate; and the carboniferous rocks often rest upon the hypogene, without exhibiting any marks of change at the junction. According to the views before explained of the operations of earthquakes, we ought not to expect plutonic and metamorphic rocks of the more modern eras to have reached the surface generally; for we must suppose many geological periods to elapse before a mass, which has assumed its particular form far below the level of the sea, can have been upraised and laid open to view above that level. Beds containing marine shells sometimes appear in the principal mountain-chains, at the height of two or three miles above the sea; but they always belong to formations of considerable antiquity: still more, then, should we be prepared to find the hypogene rocks now in sight to be of high relative antiquity, since, before they could be brought up to view, they must probably have risen from a site far inferior to the bottom of the ocean.

The cause of the great age of the plutonic and metamorphic rocks, *now in sight*, may be elucidated by a familiar illustration. Suppose two months to be the usual time required for passing from some tropical country to our island, and that an annual importation takes place of a certain species of insect which can be reared only in the climate of that equatorial country, and the ordinary term of whose life is two months. It is evident that no living individuals of that species could ever be seen in England except in extreme old age. The young may come annually into the world in great numbers; but, in order to see them, we must travel to lands near the equator.

In like manner, if the hypogene rocks can originate only at great depths in the regions of subterranean heat, and if it requires many geological epochs to raise them to the surface, they must be very ancient before they make their appearance in the superficial parts of the earth's crust. They may still be forming in every century, and they may have been produced in equal quantities during each successive geological period of equal duration; but in order to see them in a nascent state, slowly consolidating from a state of fusion, or semi-fusion, it would be necessary to descend into the "fuelled entrails" of the earth.

In the accompanying diagram, Fig. 164., an attempt is made to show the inverted order in which the sedimentary and plutonic formations may occur in the earth's crust; subterposition in the plutonic, like superposition in the sedimentary rocks, being for the most part characteristic of a newer age.

The oldest plutonic rock, No. I., supposed to have consolidated from a state of fusion before any of the fossiliferous rocks now on the surface were deposited,

Fig 164.

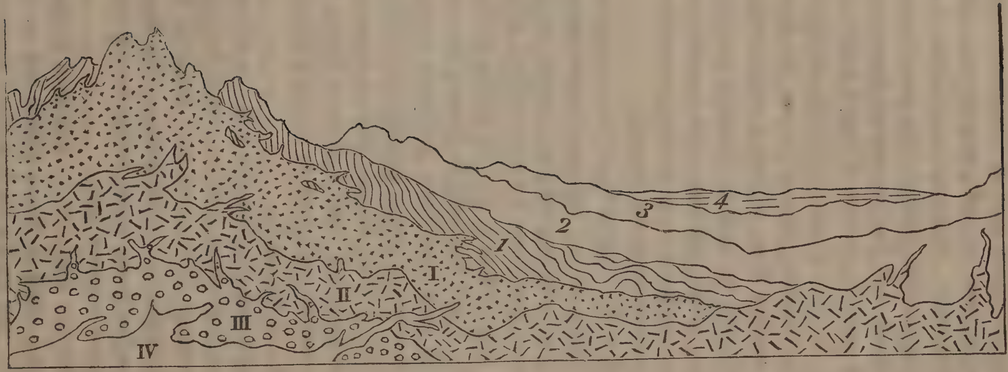


Diagram showing the relative position which the hypogene and sedimentary formations of different ages may occupy.

I. Primary plutonic.	4. Recent strata.
II. Secondary plutonic.	3. Tertiary strata.
III. Tertiary plutonic.	2. Secondary strata.
IV. Recent plutonic.	1. Primary metamorphic rocks.

has been upheaved at successive periods until it has become exposed to view in a mountain-chain. This protusion of No. I. has been caused by the igneous agency which produced the new plutonic rocks Nos. II. III. and IV. Part of the metamorphic rocks No. 1. have also been raised to the surface by the same gradual process. It will be observed that the Recent *strata* No. 4. and the Recent plutonic rock No. IV. are the most remote from each other in position, although of contemporaneous date. According to this hypothesis the convulsions of many periods will be required before *Recent* granite will be upraised so as to form the highest ridges and central axes of mountain-chains. During that time the *Recent* strata No. 4. might be covered by a great many newer sedimentary formations.

As the progress of decay and reproduction by aqueous agency is incessant on the surface of the continents, and in the bed of the ocean, while the hypogene rocks are generated below, or are rising gradually from the volcanic foci, there must ever be a remodelling of the earth's surface in the time intermediate between the origin of each set of plutonic and metamorphic rocks, and the protrusion of the same rocks into the atmosphere or the ocean. Suppose the principal source of the Etnean lavas to lie at the depth of ten miles, we may easily conceive that before they can be uplifted to the day several distinct series of earthquakes must occur, and between each of these there might usually be one or many periods of tranquillity. The time required for so great a development of subterranean movements might well be protracted until the deposition of a series of sedimentary

rocks, equal in extent to all our secondary and tertiary formations, had taken place.

The relative age, therefore, of the *visible* plutonic and metamorphic rocks, as compared to the unaltered sedimentary strata, must always be determined by the relations of two forces — the power which uplifts the hypogene rocks, and that aqueous agency which degrades and renovates the earth's surface; or, in other words, the relative age must depend on the quantity of aqueous action which takes place between two periods — that during which the heated and melted rocks are cooled and consolidated in the nether regions, and that of their emergence at the earth's surface.

Volume of hypogene rocks supposed to have been formed since the Eocene period. — If we were to indulge in speculations on the probable quantity of hypogene formations, both stratified and unstratified, which may have been formed beneath Europe and the European seas since the commencement of the Eocene period, it might be conjectured that the mass has equalled, if not exceeded in volume, the entire European continent. The grounds of this opinion will be understood by reference to what I have said of the causes which may have upheaved part of Sicily to its present height above the level of the sea since the beginning of the Newer Pliocene period.* If the theory which, in that instance, attributes the disturbance and upheavings of the superficial strata to the action of subterranean heat be deemed admissible, the same argument will apply with no less force to every other district, elevated or depressed, since the commencement of the tertiary period.

* See p. 5.

But the remarks on the map of Europe, in the first book, have shown, that the conversion of sea into land, since the Eocene period, embraces an area equal to the greater part of Europe; and that even those tracts which had in part emerged before the Eocene era, such as the Alps, Apennines, and other mountain-chains, have risen to the additional altitude of from one thousand to four thousand feet since that era. I have also suggested the probability of a great amount of subsidence, and the conversion of considerable portions of European land into sea, during the same period, — changes which may be supposed to arise from the influence of subterranean heat.

From these premises we may conclude, that the liquefaction and alteration of rocks, by the operation of volcanic heat at successive periods, has extended over a subterranean space, equal at least in area to the present European continent, and has often pervaded a portion of the earth's crust four thousand feet or more in thickness.

The principal effect of these volcanic operations in the nether regions, during the tertiary periods, or since the existing species began to flourish, has been to heave up to the surface hypogene formations of an age anterior to the carboniferous. The repetition of another series of movements, of equal violence, might upraise the plutonic and metamorphic rocks of many of the secondary periods; and if the same force should still continue to act, the next convulsions might bring up the *tertiary* and *recent* hypogene rocks; by which time we may imagine that nearly all the sedimentary strata now in sight would either have been destroyed by the action of water, or have assumed the meta-

morphic structure, or would have been melted down into plutonic and volcanic rocks.

At the end of this chapter will be found a table of the chronological relations of the principal divisions of rocks, according to the views above set forth. The sketch is confessedly imperfect; but it will elucidate the theory above suggested, of the connection which may exist between the hypogene rocks of different periods, and the alluvial, volcanic, and sedimentary formations.

Concluding Remarks.

In the history of the progress of geology, it has been stated that the opinion originally promulgated by Hutton, "that the strata called *primitive* were mere altered sedimentary rocks," was vehemently opposed for a time, on the ground of its supposed tendency to promote a belief in the past eternity of our planet.* Before that period the absence of animal and vegetable remains in the so-called primitive strata had been appealed to, as proving that there had been an era when the planet was uninhabited by living beings, and when, as was also inferred, it was uninhabitable, and, therefore, probably in a nascent state.

The opposite doctrine, that the oldest visible strata might be the monuments of an antecedent period, when the animate world was already in existence, was declared to be equivalent to the assumption that there never was a beginning to the present order of things. The unfairness of this charge was clearly pointed out by Playfair, who observed, "that it was

* Vol. I. p. 91.

one thing to declare that we had not yet discovered the traces of a beginning, and another to deny that the earth ever had a beginning."

I regret, however, to find that the bearing of my arguments in the first book has been misunderstood in a similar manner; for I have been charged with endeavouring to establish the proposition, that, "the existing causes of change have operated with absolute uniformity from all eternity."*

It is the more necessary to notice this misrepresentation of my views, as it has proceeded from a friendly critic, whose theoretical opinions coincide in general with my own; but who has, in this instance, strangely misconceived the scope of the argument. With equal justice might an astronomer be accused of asserting that the works of creation extended throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view; and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows that it must occupy a minute and infinitesimal point in infinite space.

So if, in tracing back the earth's history, we arrive

* Quarterly Review, No. 86., Oct. 1830, p. 464.

at the monuments of events which may have happened millions of ages before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity.

It has been argued, that, as the different states of the earth's surface, and the different species by which it has been inhabited, have all had their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that, as we admit the creation of man to have occurred at a comparatively modern epoch — as we concede the astonishing fact of the first introduction of a moral and intellectual being — so also we may conceive the first creation of the planet itself.

I am far from denying the weight of this reasoning from analogy; but, although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings. We aspire in vain to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time

or space, we discover every where the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe which has been suited to the accommodation of myriads of living creatures, but that many former states also have been adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates, have varied; the species likewise have been changed; and yet they have all been so modelled, on types analogous to those of existing plants and animals, as to indicate throughout a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

TABLE II.

Showing the Relations of the Alluvial, Aqueous, Volcanic, and Hypogene Formations of different Ages.

Periods.		Formations.		Some of the Localities where the Formations occur.
I. Recent.	A. Table I. p. 308.	Alluvial.	- - -	Beds of existing rivers, &c., book iii. ch. xiv.
		Aqueous.	*a.* Marine.	Coral reefs of the Pacific, book iii. ch. xviii.
			b. Freshwater.	Bed of Lake Superior, &c., book ii. ch. iv.
		Volcanic.	- - -	Etna, Vesuvius, book ii. chs. x. xi. xii.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of active volcanos, book iv. ch. xxvi.
			b. Metamorphic.	*Concealed;* around the foci of active volcanos, book iv. ch. xxvii.
II. Tertiary.	1. Newer Pliocene. B. Table I. p. 308.	Alluvial.	- - -	Gravel covering the Newer Pliocene strata of Sicily.
		Aqueous.	*a.* Marine.	Val di Noto, Sicily.
			b. Freshwater.	Colle, in Tuscany.
		Volcanic.	- - -	Val di Noto, Sicily.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Newer Pliocene volcanos — underneath the Val di Noto, Vol. IV. p. 5., and book iv. ch. xxvii.
			b. Metamorphic.	*Concealed;* near the foci of Newer Pliocene volcanos — underneath the Val di Noto, Vol. IV. p. 5. and book iv. ch. xxvii.

TABLE II. — *continued.*

	Periods.	Formations.		Some of the Localities where the Formations occur.
II. Tertiary — *continued.*	2. Older Pliocene. C. Table I. p. 308.	Alluvial.	- - -	Norfolk? Vol. IV. p. 91.
		Aqueous.	*a.* Marine.	Subapennine formations, Vol. IV. p. 63.
			b. Freshwater.	Near Sienna, Vol. IV. p. 69.
		Volcanic.	- - -	Tuscany, Vol. IV. p. 68.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Older Pliocene volcanos — beneath Tuscany.
			b. Metamorphic.	*Concealed;* probably near the same foci.
	3. Miocene. D. Table I. p. 308.	Alluvial.	- - -	Mont Perrier, Auvergne — Orleanais, Vol. IV. pp. 147. 150.
		Aqueous.	*a.* Marine.	Bordeaux. Dax.
			b. Freshwater.	Saucats, near Bordeaux, Vol. IV. p. 134.
		Volcanic.	- - -	Hungary, Vol. IV. p. 153.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Miocene volcanos — beneath Hungary.
			b. Metamorphic.	*Concealed;* probably around the same foci.
	4. Eocene. E. Table I. p. 309.	Alluvial.	- - -	Summit of North and South Downs? Vol. IV. p. 276.
		Aqueous.	*a.* Marine.	Paris and London basins.
			b. Freshwater.	Isle of Wight — Auvergne.
		Volcanic.	- - -	Ronca, Vicentine, Vol. IV. p. 224.; oldest volcanic rocks of the Limagne d'Auvergne, book iv. ch. xix.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Eocene volcanos — beneath Vicentine and the Limagne d'Auvergne.
			b. Metamorphic.	*Concealed;* probably near the same foci.

TABLE II. — *continued.*

Periods.		Formations.		Some of the Localities where the Formations occur.
III. SECONDARY.	1. Cretaceous group. F. Table I. p. 309.	Alluvial.		
		Aqueous.	*a.* Marine. *b.* Freshwater.	Wiltshire, North Downs. Flamborough Head.
		Volcanic.	- - -	Northern Flanks of the Pyrenees? Near Dax?
		Hypogene.	*a.* Plutonic. *b.* Metamorphic.	
	2. Wealden group. G. Table I. p. 309.	Alluvial.	- - -	Portland "Dirt-bed" (containing pebbles).
		Aqueous.	*a.* Marine. *b.* Freshwater.	Weald of Surrey, Kent, and Sussex, book iv. ch. xxi.
		Volcanic.		
		Hypogene.	*a.* Plutonic. *b.* Metamorphic.	
	3. Oolite group. H. Table I. p. 310.	Alluvial.		
		Aqueous.	*a.* Marine. *b.* Freshwater.	Oxford. Bath. Jura chain.
		Volcanic.	- - -	Hebrides?
		Hypogene.	*a.* Plutonic. *b.* Metamorphic.	*Concealed;* beneath the Hebrides.
	4. Lias group. I. Table I. p. 311.	Alluvial.		
		Aqueous.	*a.* Marine. *b.* Freshwater.	Lyme Regis. Whitby. Aberthaw.
		Volcanic.	- - -	Hebrides?
		Hypogene.	*a.* Plutonic. *b.* Metamorphic.	Alps? book iv. ch. xxvii. Valorsine in Savoy?
	5. New Red Sandstone and Magnesian limestone group. K. & L. Table I. p. 311.	Alluvial.		
		Aqueous.	*a.* Marine. *b.* Freshwater.	Cheshire. Staffordshire. Vosges. Westphalia (Muschelkalk).
		Volcanic.	- - -	Near Exeter, Devon.
		Hypogene.	*a.* Plutonic. *b.* Metamorphic.	*Concealed;* beneath Devonshire?

TABLE II. — *continued.*

Periods.		Formations.		Some of the Localities where the Formations occur.
III. Secondary — *continued.*	6. Carboniferous & Old Red Sandstone group. M. & N. Table I. p. 312.	Alluvial.		
		Aqueous.	*a.* Marine.	Clifton. Mendip. Edinburgh.
			b. Freshwater.	Coal measures of North of England and near Edinburgh.
		Volcanic.	- - -	Forfarshire. Edinburgh. Fife. Durham. High Teesdale.
		Hypogene.	*a.* Plutonic.	*Concealed;* beneath Edinburgh, Northumberland, Durham.
			b. Metamorphic.	Near the Plutonic rocks of the same period.
IV. Transition.	7. Silurian & Greywacké group. O. & P. Table I. p. 313.	Alluvial.		
		Aqueous.	*a.* Marine.	Wenlock, Shropshire.
			b. Freshwater.	
		Volcanic.	- - -	Shropshire.
		Hypogene.	*a.* Plutonic.	*Concealed;* beneath Shropshire.
			b. Metamorphic.	Near the Plutonic rocks of the same period.
V. Primary Rocks.*		Alluvial. Aqueous. Volcanic.	- - -	Probably all destroyed by denudation, or converted into hypogene.
		Hypogene.	Plutonic.	Perhaps a considerable part of the granite now visible.
			Metamorphic.	Probably a large proportion of the gneiss, mica-schist, and other stratified crystalline rocks now visible.

* By primary formations are meant those, whether stratified or unstratified, which are older than the most ancient European rocks (the transition or greywacké), in which distinct fossils have as yet been discovered.

INDEX.

A.

Aberdeenshire, passage from trap into granite in, iv. 355.
Abesse, inland cliff at, iv. 136.
Abo, ii. 335, 336.
Acquapendente, volcanic tuffs at, iv. 69.
Adams, Mr., on fossil elephant, i. 147.
Adanson on age of the baobab tree, iii. 451.
Addington hills, iv. 226.
Addison on Burnet's theory, i. 55.
Adernò, dip of strata near, iii. 424.
Adige, embankment of the, i. 276. ; iii. 192.
——, delta of the, i. 346.
Adour, R., new passage formed by, ii. 76.
——, tertiary strata of, iv. 133.
Adria, formerly a sea-port, i. 347.
Adriatic, deposits in, i. 63. 66. 124. 347. ; iii. 295.
——, gain of land in, i. 347.
——, its form and depth, i. 347.
Adur, R., transverse valley of, iv. 251.
Africa, fossil shells of, mentioned by ancients, i. 24.
——, heat radiated by, i. 164.
——, currents on coast of, ii. 73. 84.
——, drift sands of deserts, iii. 210.
——, shaken by earthquake, ii. 297.
——, devastations of locusts in, iii. 116.
——, strata forming off coast of, iii. 295.
——, desert of, its area, iii. 152.
Agassiz, M., on fossil fish, i. 198. 230. ; iii. 380. ; iv. 88. 125. 192. 290. 301. 303.
Agricola on fossil remains, i. 36.
Ahmedabad town, destroyed by earthquake, ii. 237.
Aidat, lake, how formed, iv. 213.
Air, circulation of, i. 183.
Airthrey, fossil whale found at, iii. 290.
Airy, Professor, i. 180.
Aix, in Provence, tertiary strata of, iv. 223.
——, fossil insects of, iv. 223.
Albenga, tertiary strata at, iv. 77, 78.
Aldborough, incursions of sea at, ii. 34.
Alderney, Race of, ii. 6.
Aleppo, earthquake of, ii. 237.
Aleutian isles, eruptions, &c. in, ii. 99. 248.
Algæ, depths at which some species live, iii. 30.
Allan, Mr. T., on mammiferous fossils of Isle of Wight, i. 236. ; iv. 229.
Allier, R., volcanic tuff, &c. on its banks, iv. 198.
Alloa, whale cast ashore at, iii. 289.
——, fossil whale found near, iii. 290.
Alluvium, definition of, iii. 218.
——, formed in all ages, iv. 57.
——, imbedding of organic remains in, iii. 219.
——, marine, iii. 220.
——, volcanic, ii. 146.
——, in Scotland, ii. 285.
——, stalagmite alternating with, in French caves, iii. 232.
——, European, in great part tertiary iii. 58.
——, of newer Pliocene period, iv. 51. 57. 61.
——, of Miocene era, iv. 147.
——, of Eocene period, iv. 247. 276.
——, under lavas, iv. 109. 111. 114. 209.
——, in ancient fissures, iv. 211.
Alps, Saussure on the, i. 79.
——, tertiary rocks of the, i. 205.

Alps, greatly raised during tertiary epoch, i. 214.
——, shells drifted from the, iii. 382.
——, erratic blocks of the, iv. 59.
——, maritime, tertiary strata at base of, iv. 75.
——, secondary strata penetrated by granite in the, iv. 351.
——, strata of oolite altered in the, iv. 376.
Altered strata in contact with granite, iv. 374.
——, enumeration of the probable conversions of sedimentary strata into well-known metamorphic rocks, iv. 382.
Alting, on the Zuyder Zee, ii. 57.
Alum Bay, alternation of London and plastic clay in, iv. 226.
Alzey, tertiary strata of, iv. 145.
Amalfi, i. 122.
Amazon, R. sea discoloured by waters of, ii. 85.
——, land formed by its deposits, ii. 85.
——, animals floated down on drift wood by, iii. 63.
Amer, structure of country near, iv. 104.
America, its coast undermined, ii. 60.
——, lakes of, may cause deluges, i. 130.
——, recent strata in lakes of, i. 340.; iii. 285.
——, specific distinctness of animals of, iii. 23. 48.
——, domesticated animals have run wild in, ii. 438; iii. 134.
Amiata, Mount, i. 310.
Amici, Vito, on Moro's system, i. 66.
Ammonia in lavas, ii. 395.
Amonoosuck, flood in valley of, i. 209.
Ampère, M., on currents of electricity in the earth, ii. 367.
Anapo, valley of, iv. 10.
Andernach, loess and volcanic ejections alternating at, iv. 48.
Andes, changes of level in, iii. 273.
——, height of perpetual snow on, i. 190.
——, volcanos of, ii. 93. 95.
Anglesea, changes caused by a volcanic dike in, iv. 371. 385.
Animals, Lamarck's theory of the production of new organs in, ii. 412.
——, imported into America, have run wild, ii. 438.; iii. 134.
Animals, aptitude of some kinds to domestication, ii. 452. 462.
——, hereditary instincts of, ii. 453.
——, domestic qualities of, ii. 452. 457.
——, their acquired habits rarely transmissible, ii. 457. 465.
——, changes in the brain of the fœtus in vertebrated, iii. 18.
——, plants diffused by, iii. 38.
——, their geographical distribution, i. 199.; iii. 48. 50. 52.
——, migrations of, iii. 54. 57.
——, causes which determine the stations of, iii. 107. 119.
——, influence of man on their distribution, iii. 130.
——, fossil, in peat, caves, &c., iii. 204. 208. 219. 223. 251. 256.
Anio, R., flood of the, i. 294.
——, once flowed through a chain of lakes, i. 320.
Anning, Miss M., on waste of cliffs, ii. 49.
Annus Magnus, duration of, i. 12.
Anoplotherium in freshwater formation of I. of Wight, iv. 229. 276.
Anthracite, whence derived, iv. 383.
Anticlinal axis of Weald valley, iv. 237. 244.
Anticlinal lines; how far those formed at the same time are parallel, iv. 340.
Antilles, earthquake in the, ii. 251.
Antissa, i. 17.
Antrim, chalk in, converted into marble by trap-dike, iv. 372.
——, altered coal and lias in, iv. 373.
Apennines, their relative age, i. 204 214.
——, tertiary strata at foot of, iv. 63.
Aphides, White's account of a shower of, iii. 86.
——, their multiplication, iii. 114.
Apollinaris cited, iv. 213.
Apure, R., horses drowned in, iii. 253.
Aqueous causes, i. 254.
Aqueous lavas, description of, ii. 130. 146.; iii. 214.
Arabian Gulf, filling with coral, iii. 301.
——, volcano at its entrance, ii. 110.
Arabian writers, i. 23. 28.
Arago, M., on influence of forests on climate, iii. 190.
——, on solar radiation, i. 221.
Arbroath, houses, &c. swept away by sea at, ii. 19.

Arduino, memoirs of, 1759, i. 17.
——, on submarine volcanos, i. 72. 125.
Aristarchus, i. 295.
Aristophanes, i. 15.
Aristotelian system, i. 20.
—— theory of spontaneous generation, i. 37.
Arno, R., yellow sand like Subapennine deposited by, iv. 70.
Arso, volcanic eruption of, in Ischia, ii. 122.
Artesian wells, phenomena brought to light by, i. 298.
——, depth from which water rises in, i. 299.
Arun, transverse valley of the, iv. 251.
Arve, sediment transported by the, i. 341.
——, section of débris deposited by, i. 374.
Asama-yama, eruption of, ii. 252.
Ascension, island of, fossil eggs of turtle from, iii. 290.
Ashes, volcanic, transported to immense distances, ii. 243.
Asia, subject to earthquakes, i. 13.
——, coast of, changed, i. 29.
——, causes of extreme cold of part of, i. 164.
——, Minor, gain of land on coast of, ii. 84.
——, Western, great cavity in, i. 130.; iii. 148. 371.
——, this now disproved, iv. 215.
Ass, wild in Quito, iii. 136.
——, wild in Tartary, iii. 59.
Astroni, crater of, iv. 107.
Astruc on delta of Rhone, i. 343.
Atchafalaya, R., drift-wood in, i. 282.
——, section of the banks of, i. 361.
Athabasca lake, drift-wood in, iii. 244.
Atlantic, mean depth of, i. 180.
——, its relative level, ii. 62.
——, rise of the tide in, ii. 63.
Atlantis, submersion of, i. 13.; iv. 316.
Atrio del Cavallo, ii. 140.; iv. 23.
Aubenas, fissures filled with breccia near, iii. 232.
Aurillac, freshwater formation of, iv. 171.
Australia, kangaroo and emu thinning in, iii. 133.
——, coral reefs of, iii. 301.
——, tertiary strata of, iv. 40.
——, breccias of, bones of marsupial animals in, iv. 56.
Auvergne, salt deposited by springs in, i. 327.
——, carbonic acid gas disengaged in, i. 327.
——, lavas of, iii. 445.
——, alluviums of, iv. 147. 208.
——, volcanic rocks of, i. 85, 86.; iii. 387.; iv. 155. 197.
——, lacustrine deposits of, iv. 157.
——, map of lacustrine basins and volcanic rocks of, iv. 158.
——, tertiary red marl and sandstone of, like new red sandstone, iv. 161. 323.
——, indusial limestone of, iv. 165.
——, connexion of Paris basin and, iv. 178.
——, igneous rocks associated with lacustrine in, iv. 198.
——, volcanic breccias of, iv. 147. 200.
——, minor volcanos of, iv. 201. 205.
——, ravines in lavas of, iv. 207, 208.
Ava, mammiferous fossils of, i. 48.
——, fossil wood of, i. 48.
Aventine, Mount, tufa on, iv. 43.
Avernus, lake, ii. 117.
Avicenna on cause of mountains, i. 29.
Azof sea, said to have been united with Caspian, ii. 104.
——, new island thrown up in, ii. 105.
Azores, icebergs drifted to the, i. 173. 267.
——, siliceous springs of, i. 323.

B.

Babbage, Mr. on the coast near Puzzuoli, ii. 313.
——, on Temple of Serapis, ii. 325.
——, on expansion of rocks by heat, ii. 383.
Bacon, Lord, cited, iii. 280.
Baden, gypseous springs of, i. 322.
Baffin's Bay, icebergs in, i. 168.
Bagnes, valley of, bursting of a lake in the, i. 291.
Bagneux, strata near, iv. 181.
Bagshot sand, its composition, &c., iv. 228.
Baiæ, changes on coast of the bay of, ii. 312. 321.
——, ground plan of the coast of, ii. 312.
——, sections in bay of, ii. 314. 316.
Bakewell, Mr., on formation of soils, iii. 178.
——, on fall of Mount Grenier, iii. 222.

Bakewell, Mr., on jointed structure in rocks, iv. 366.
Bakewell, Mr., Jun., on Falls of Niagara, i. 273.
Bakie loch, charæ fossil in, iii. 283.
Baku, inflammable gas of, i. 18.; ii. 103.
Balaruc, thermal waters of, i. 343.
Baldassari, on Sienese fossils, i. 67.
Ballard, M., on state of buried bones, iii. 236.
Baltic sea, deltas of the, i. 340.
——, lowering of level of the, i. 340. ii. 331.
——, drifting of rocks by ice in, i. 267.
——, currents on its shores, ii. 64.
Banos del Pujio, elevated sea-cliff near, iv. 32.
Baobab tree, its size, probable age, &c., iii. 451.; iv. 217.
Barbadoes, rain diminished by felling of forests in, iii. 187.
Barcelona, tertiary strata of, iv. 114.
Barcombe, in Sussex, iv. 247.
Bargone, gypsum in marls near, iv. 68.
Barren island, a supposed crater of elevation, ii. 218.
Barrow, Mr., on a bank formed in sea by locusts, iii. 117.
Barrow, Mr., Jun., on the Geysers of Iceland, i. 324.; ii. 386.
Barsoe, loss of land in island of, ii. 65.
Barton, Mr., on geography of plants, iii. 23.
Basalt, opinions of the earlier writers on, i. 84, 85.; iii. 329.
Basterot, M. de, on fossil shells of Bordeaux and Dax, iii. 360.; iv. 132.
Batavia, effects of earthquake at, ii. 304.
Battoch, Mount, granite veins of, iv. 349.
Baumhauer, Mr., on a river-flood in Java, iii. 255.
Bauza, his chart of Gulf of Mexico, ii. 86.
Bawdesey, crag strata near, iv. 92.
Bay of Bengal, its depth, i. 355.
Bayfield, Capt., on geology of Lake Superior, i. 338.
——, on bursting of a peninsula by Lake Erie, ii. 64.
——, on elevated beaches in Gulf of St. Lawrence, ii. 99. iv. 35.
——, on earthquakes in Canada, ii. 251.
——, on arrangement of strata in Gulf of St. Lawrence, iv. 72.
Bayonne, strata near, iv. 334.
Beachey Head, ii. 43. iv. 241.
Bears, once numerous in Wales, iii. 132.
——, black, migrations of, iii. 57.
——, drifted on ice, iii. 124.
Beauchamp, palæotherium of, iv. 192.
Beaufort, Capt., on gain of land on coast of Asia Minor, ii. 84.
——, on rise of tides, ii. 3.
Beaumont, M. Elie de, on mountains in the moon, ii. 222.
——, on greywacké fossils, i. 196.
——, on force of modern earthquakes, ii. 401.
——, on cause of the deluge, iv. 218.
——, his theory of contemporaneous origin of parallel mountain chains considered, iv. 327.
——, on modern granite of the Alps, iv. 351.
Beaver, once an inhabitant of Scotland and Wales, iii. 131.
——, remains of, in shell-marl, in Perthshire, iii. 256.
Bee, migrations of the, iii. 85.
Beechey, Capt., on elevation of Bay of Conception, ii. 300.
——, on drifting of canoes in Pacific, iii. 93.
——, on temple of Ipsambul, iii. 211.
——, on coral islands in Pacific, iii. 303. 308. 318.
——, on recent changes of level in Pacific, iii. 319.
Beginning of things, supposed proofs of, iv. 398.
Behat, buried town near, iii. 221.
Belbet, near Aurillac, iv. 173.
Belcher, Capt., on elevation of Conception Bay, ii. 300.
——, on strata forming off coast of Africa, iii. 295.
Belgium, tertiary formations of, iv. 223.
Beliemi, Mount, caves in, iv. 55.
Bell rock, large stones thrown up by storms on the, ii. 20.
Belzoni, on temple of Ipsambul, iii. 211.
——, on a flood of the Nile, iii. 258.
Benin, currents in bay of, ii. 4.
Bérard, M., on depth of Mediterranean ii. 71.
Bergmann, on waste of Yorkshire coast, ii. 24.
Berkeley, on recent origin of man, iii. 278.

Bermudas, coral reefs of the, iii. 301. 305.
Berzelius, on density of sea-water, i. 168.
Beshtau, earthquakes in, ii. 294.
Beudant, M., on volcanic rocks of Hungary, iv. 153.
Bewick, cited, ii. 33. iii. 68. 132.
Bhooj, town of, destroyed by earthquake, ii. 237.
——, volcanic eruption at, during Cutch earthquake, ii. 237. iii. 216.
Bies Bosch; new bay formed in Holland, ii. 56.
Bigsby, Dr., on North American lakes, i. 339. ; iii. 285.
Bingen, gorge of, iv. 49.
Binstead, fossils of, iv. 229. 276.
Birds, diffusion of plants by, iii. 39.
——, geographical distribution of, iii. 66. 95.
——, their powers of diffusion, iii. 68.
——, migrations of, iii. 68.
——, recent extermination of some species of, iii. 132.
——, bones of, in Gibraltar breccia, iii. 231.
——, rarity of their remains in new strata, iii. 250.
Bischoff, Professor, cited, iv. 379.
Biscoe, Capt., his discoveries in the south Polar Seas, i. 171.
Bison, fossil, in Yorkshire, i. 142.
Bisons, in Mississippi valley, iii. 56.
Bistineau, a lake formed by Red River, i. 286.
Bitumen, oozing from the bottom of the sea, near Trinidad, i. 330.
Bituminous springs, i. 330.
——, shales, i. 331.
Bize, cave at, iii. 235.
Bizona, town submerged, i. 26.
Black Lake, i. 286.
Black Sea, calcareous springs near, i. 322.
——, waste of cliffs in the, ii. 64.
——, evaporation of the, ii. 67.
——, *see* Euxine.
Blavier, M., on peat, iii. 201.
Blaye, limestone of, iv. 134.
Bloomfield, bursting of peat-moss near, iii. 208.
Blown sand, imbedding of organic remains, &c. in, iii. 210.
Blue Mountains in Jamaica, ii. 309.
Bluffs of Mississippi described, i. 279. 281.
Boa Constrictor, migration of, iii. 72.
Boase, Mr., on inroads of sea in Cornwall, ii. 49, 50.
——, on drift-sand in Cornwall, iii. 213.
——, on chemical composition of rocks, iv. 383.
Boate, Dr., on Irish peat-bogs, iii. 200.
Boblaye, M., on ceramique, in Morea, iii. 222.
——, on engulphed rivers in Morea, iii. 226.
——, on caves of the Morea, iii. 226.
——, on earthquakes in Greece, iii. 229.
——, on successive elevations of the Morea, iv. 34.
——, on tertiary strata of Morea, iv. 84.
——, on cretaceous rocks of Morea, iv. 288.
Bog iron-ore, whence derived, iii. 204.
Bogota, earthquake of, ii. 230.
Bohemia, age of metallic veins of, iv 382.
Bolos, Don Francisco, on volcanos of Catalonia, iv. 107. 112. 114.
——, on destruction of Olot by earthquake, in 1421, iv. 112.
Bonajutus, on subsidence of coast of Sicily, ii. 306.
Bonaparte, C., on birds, iii. 68.
Bonelli, Signor, on fossils of the Superga, iii. 386. ; iv. 138.
——, on fossil shells of Savona, iv. 78.
Bonn, casts of freshwater shells in quartz, near, iv. 125.
Bonpland, on plants common to Old and New World, iii. 26.
Bordeaux, tertiary strata of, iii. 360. ; iv. 132. 134.
Bore, a tidal wave frequent in the Bristol Channel and the Ganges, ii. 61.
Bormida, tertiary strata of valley of the, iii. 386. ; iv. 139.
Bory de St. Vincent, M., on isle of Santorin, ii. 206. 210.
Boscomb chine, ii. 46.
Bosphorus, ii. 67. 104.
Botanical geography, iii. 24.
——, provinces, their number, iii. 28.
——, how caused, iii. 101.
——, why not more blended together, iii. 103.
Bothnia, Gulf of, gradual elevation of the coast of, i. 212. 340. ; ii. 332.
——, drifting of rocks by ice in, i. 267.
Botley Hill, height of, iv. 237.
Boué, M., on the Pyrenees, i. 206.

Boué, M., on the coal strata, i. 197.
——, on loess of the Rhine, iv. 51.
——, on value of zoological characters in determining the chronological relations of strata, iv. 135.
——, on tertiary formations of Hungary and Transylvania, iv. 141. 154.
——, on the Vicentine, iv. 224.
——, on theory of M. de Beaumont, iv. 338. 340.
Bouillet, M., on extinct quadrupeds of Mont Perrier, iv. 149. 210.
——, on alluviums of different ages in Auvergne, iv. 210.
Boulade, alluviums of the, iv. 147.
Boulon and Ceret, dip of tertiary strata between, iv. 83.
Bourbon, island, volcanic, ii. 110. ; iv. 357.
Bourdones, R., shoal upheaved at its mouth, ii. 251.
Bournmouth, submarine forest at, iii. 276.
Boussingault, M., on volcanos of the Andes, ii. 95, 96.
——, on gases evolved by volcanos, ii. 392.
Bowditch, Mr., on fossil shells of Madeira, iv. 38.
Boyle on bottom of the sea, i. 43.
Bracini on Vesuvius before 1631, ii. 129.
Braganza, R., iv. 70.
Brahmins, their doctrines, i. 9.
Brand, Rev. J. F., on birthplace of man, iii. 89.
Brander on fossils of Hampshire, i. 76.
Bray, valley of, iv. 297.
Breaks in series of superimposed formations, causes of, iii. 367. 373.
Breccias, in Val del Bove, iii. 445.
——, in caves, iv. 51. 56.
——, now in progress in the Morea, iii. 227.
——, volcanic, of Auvergne, iv. 147. 200.
Brenta, delta of the, i. 346.
Brieslak, on the temple of Serapis, ii. 321. 323.
——, on lavas of Vesuvius, ii. 142.
Briggs, Mr., his discovery of water in African desert, i. 300.
Brighton, waste of cliffs of, ii. 44.
——, strata at base of cliffs at, ii. 41. ; iv. 274. 280.
Brine, springs, i. 326.
Bristol Channel, currents in, ii. 6.
Britany, a village in, buried under blown sand, iii. 213.
——, marine tertiary strata of, i. 211.
Brocchi on fossil conchology, i. 33.
——, on Burnet's theory, i. 58.
——, his account of writers on delta of Po, i. 347.
——, on extinction of species, iii. 104.
——, on the Subapennines, i. 203. ; iii. 357. ; iv. 63. 74.
Broderip, Mr., on opossum of Stonesfield, i. 233.
——, on shells from Conception Bay, ii. 301.
——, on *Ianthina fragilis*, iii. 77.
——, on bulimi restored to life after long abstinence, iii. 78.
——, on moulting of crabs, iii. 81.
——, on naturalization of a foreign land-shell, iii. 97.
Bromberg, a vessel and two anchors dug up near, iii. 267.
Bromley, pebble with oysters in plastic clay at, iv. 225.
Brongniart, M. Ad., on fossil plants of the coal formation, i. 154.
——, on plants in islands, i. 191.
Brongniart, M. Alex., on modern lava-streams, ii. 185.
——, on elevated beaches in Sweden, i. 211. ; ii. 342.
——, on the Paris basin, iii. 354. ; iv. 179. 185.
——, on conglomerate of the Superga, iv. 139.
Bronn, Prof., on fossil shells of the Superga, iii. 389.
——, on tertiary formations of Italy, iii. 389.
——, on loess of the Rhine, iv. 46. 51.
——, on tertiary strata of Mayence, iv. 145.
Bronte, eruption of Etna near, ii. 174.
Browallius, on filling up of Gulf of Bothnia, ii. 335.
Brown, Mr., on plants common to Africa, Guiana, and Brazil, iii. 36.
Brown coal formation near the Rhine, iv. 123.
Bruel, quarry of, iv. 173.
Buckland, Dr., on fossil elephants, &c. in India, i. 9.
——, on fossils from Eschscholtz's Bay, i. 149.
——, on the Bristol coal-field, i. 200.

Buckland, Dr., on mammiferous remains of Isle of Wight, i. 236.
——, on fossils in caves and fissures, iii. 230. 232. 234.
——, on Val del Bove, iii. 430.
——, on effects of the deluge, iv. 216.
——, on the Plastic clay, iv. 225.
——, on former continuity of London and Hampshire basins, iv. 232.
——, on valleys of elevation, iv. 259. 262.
——, on fossil forest of I. of Portland, iv. 295.
——, on oolite fossils, iv. 317.
Budoshagy, solfatara of, iv. 155.
Bufadors, jets of air from subterranean caverns called, iv. 111.
Buffon, his theory of the earth, i. 67.
——, reproved by the Sorbonne, i. 68.
——, on animals of Old as compared to New World, iii. 22.
——, on geographical distribution of animals, iii. 48.
——, on extinction of species, iii. 165.
Bulimus montanus drifted from Alps, iii. 382.
Bura and Helice, submerged Grecian towns, i. 26. ; ii. 108. ; iii. 278.
Burckhardt cited, iii. 211, 212.
Burdiehouse fossils, i. 198. ; iv. 302.
Buried cones on Etna, sections of, iii. 438.
Burkart, Mr., on Jorullo, ii. 190.
Burnes, Capt. A., on earthquake of Cutch, 1819, ii. 238.
——, on earthquake in valley of the Oxus, ii. 102.
Burnet, his theory of the earth, i. 54.
Burntisland, whale cast ashore near, iii. 289.
Burrampooter, bodies of men, deer, &c. floated off by, iii. 254.
——, delta of the, i. 354.
Burton, Mr. J., on tertiary strata near Red Sea, iv. 39.
Bustards, recently extirpated in England, iii. 132.
Butler, Burnet's theory ridiculed by, i. 55.
Byron, Lord, on permanency of the ocean, ii. 330.

C.

Cadibona, lignites of, iv. 152.
Cado lake, i. 286.
Caernarvonshire, tertiary strata in, i. 210. ; iv. 39.
Cæsar cited, i. 26. ; iv. 213.
Cairo, fossil shells at, iv. 139.
Caithness schists, fossils in, i. 230.
Calabria, geological description of, ii. 257.
——, earthquake of 1783 in, ii. 254.
——, animals preserved in fissures in, iii. 231.
——, tertiary strata of, i. 138. ; iii. 362.
Calais, ripple marks formed by the winds on dunes near, iv. 94.
Calanna, lava of Etna turned from its course by hill of, iii. 435.
——, valley of, iii. 434. 442.
Calcaire grossier of Paris basin, iv. 181, 182. 186. 192.
Calcaire siliceux of Paris basin, iv. 183.
Calcareous springs, i. 307.
Calcutta, beds cut through in sinking a well at, i. 357.
Caldeira, siliceous sinter of the, i. 323.
Caldera, in Isle of Palma, ii. 213. ; iii. 311.
——, a supposed crater of elevation, ii. 214.
California, five volcanos in, ii. 97.
Callao, town destroyed by sea, ii. 105.
——, changes caused by earthquakes in, ii. 302, 303. ; iii. 273.
Caltibiano, R., lava excavated by, i. 270.
Caltagirone, blue shelly marl of, iii. 410.
Caltanisetta, tertiary strata at, iii. 410.
Camden cited, ii. 50.
Camels, carcasses of, imbedded in drift sand, iii. 212.
Campagna di Roma, calcareous deposits of, i. 316.
——, volcanic rocks of, iv. 102.
Campania, aqueous lavas in, iii. 214.
——, tertiary formations of, iv. 16.
——, comparison of recorded changes in, with those commemorated by geological monuments, iv. 16.
——, age of volcanic and associated rocks of, iv. 26.
——, external configuration of the country, how caused, iv. 27.
——, affords no signs of diluvial waves, iv. 29.
Campbell, Mr., on migration of quaggas in South Africa, iii. 59.
Camper on facial angle, iii. 15.

Canada, earthquakes frequent in, ii. 98. 251.
Canary islands, eruptions in, ii. 110.
Cannon in calcareous rock, iii. 269.
——, account of one taken up near the Downs, iii. 269.
Canoes drifted to great distances, iii. 92.
——, fossil, iii. 268.
Canopus, formerly an island, i. 350.
——, overwhelmed by the sea, i. 352.
Cantal, Plomb du, ii. 204. 221.
——, freshwater formations of, iv. 171.
Capellbacken, shelly deposit at, ii. 342.
Cape May, encroachment of sea at, ii. 60.
—— of Good Hope, icebergs seen off, i. 173.
—— Wrath, granite veins of, iv. 346.
Capitol, hill, calcareous tufa on, iv. 43.
Capo Santa Croce, shelly limestone resting on lava at, iii. 412.
Capra, rock of, iii. 443.
Caraccas, earthquakes in, ii. 245. 251.
Caradoc sandstones, iv. 283, 284. 306.
Carang Assam volcano, ii. 245.
Carbonated springs, i. 327.
Carbonic acid gas; its effects on rocks, i. 327. 329.; iv. 381.
Carboniferous series, i. 196. 230.; iv. 301.
——, freshwater strata in, iv. 302.
——, *see* Coal.
Carcare, tertiary strata of, iv. 134. 139.
Cardiganshire, tradition of loss of land in, ii. 50.
Cardium porulosum, iv. 188.
Cardona, rock salt of, its relative age, iv. 323.
Carelli, Signor, on temple of Serapis, ii. 318.
Carew on St. Michael's mount, ii. 49.
Cariaco, bed of sea raised near, ii. 294.
Caribbean sea, tides in, ii. 63.
Caridi, R., its course changed by earthquakes, ii. 274.
Carpenter, Dr. on encroachment of sea at Lyme Regis, ii. 49.
Casalmaggiore, island at, carried away by the Po, i. 276.
Casamicciol, shells in tuff at, iv. 27.
Caspian, Pallas on former extent of, i. 79.
——, calcareous springs near the, i. 322.
——, evaporation of the, i. 346.
——, earthquakes on its borders, ii. 103.
——, said to encroach on the land, ii. 103.
Caspian, inflammable gas, &c. near, ii. 103.
——, its level, ii. 103.; iii. 48. 371.
——, now found not to be lower than the Black Sea, iv. 215.
——, said to have been united with Black Sea and sea of Azof, ii. 104.; iii. 66.
Cassander cited, i. 12.
Castell de Stolles, ravine excavated in lava opposite, iv. 109.
Castell Follitt, lava stream of, iv. 104.
——, lava cut through by river at, iv. 110.
Castello d'Aci, iii. 429.
Castrogiovanni, section of Val di Noto series at, iii. 407.
——, hill of, its height, iii. 409.
——, fossils of, iii. 411.
Catalonia, devastation of torrents in, iii. 186.
——, volcanic district of, iv. 103.
——, ravines excavated through lava in, iv. 108. 110.
——, age of volcanos of, iv. 112.
——, superposition of rocks in volcanic district of, iv. 113.
Catania, overwhelmed by lava, ii. 171.; iii. 215.
——, destroyed by earthquakes, ii. 306.
——, tools discovered in digging a well at, iii. 266.
——, volcanic conglomerates forming on beach at, iii. 417.
——, plain of, iii. 420.
——, marine formation near, iii. 425.
Catastrophes, theories respecting, i. 12. iii. 331. 376.
Catcliff, Little, section of, iv. 93.
Catcott on the deluge, i. 73.
—— on traditions of deluges in different countries, i. 73.
Catodons, stranded, iii. 289.
Cattegat, devastations caused by current in the, ii. 64.
Catwyck, loss of land at, ii. 56.
Caucasus, calcareous springs of, i. 321.
——, earthquakes frequent in, ii. 105. 294.
——, abounds in hot springs, ii. 105.
Cautley, Capt., on buried Hindoo town, iii. 221.
—— on bones in ancient wells, iii. 230.
Cavalaccio, Monte, shells in tuffs of, iii. 425.
Cavanilles on earthquake of Quito, ii. 250.

Caves, organic remains in, iii. 223. 227. 235.; iv. 51. 55, 56.
——, alternations of sediment and stalagmite in some, iii. 232.
—— on Etna, ii. 173.
Cavo delle Neve, in Ischia, iv. 28.
Cayambe, volcano, ii. 95.
Cellent, lava current of, iv. 104.
——, section above bridge of, iv. 108.
Celestial mountains, i. 144.
Celsius on diminution of Baltic, i. 57.; ii. 331.
Censorinus, i. 20.
Central France, lavas excavated in, i. 268.
——, comparison between lavas of Iceland and, ii. 182. 184.
——, volcanic rocks of, iv. 155. 197.
——, freshwater formations of, iv. 157.
——, analogy of tertiary deposits of, to those of Paris basin, iv. 177. 185.
Central heat and fluidity, theory of, i. 216.; ii. 356.
Centrifugal force, ii. 352. 372.
Cephalaspis, fish fossil in old red sandstone (*see* fig.) iv. 303.
Cephalonia, earthquakes in, ii. 258.
Cer, valley of, sections in the, iv. 174.
Ceret and Boulon, tertiary strata between, iv. 83.
Cesalpino on organic remains, i. 37.
Cetacea, geographical range of, iii. 54.
——, migrations of the, iii. 65.
——, imbedding of their remains in recent strata, iii. 289.
——, stranded on low shores, iii. 289.
Chabriol, M., on fossils of Mont Perrier, iv. 149.
Chadrat, pisolitic limestone of, iv. 165.
Chagos coral isles, iii. 302.
Chalk, protruded masses of, in the crag strata, iv. 98.
——, indentations filled with sand, &c. on its surface, iv. 230.
——, tertiary outliers on, iv. 231.
—— and upper green sand of Weald valley, iv. 236.
——, escarpments of Weald valley, once sea-cliffs, iv. 240, 241.
——, why no ruins of, on central district of the Weald, iv. 247.
—— of North and South Downs, its former continuity, iv. 257.
——, furrows on the, how caused, iv. 230.
Chalk, greatest height of, in England, 272.
——, area covered by, iv. 287.
——, converted into marble by trap dike in Antrim, iv. 372.
Chalk-flints, analysis of, iv. 173.
Chaluzet, calcareous spring at, i. 308.
——, volcanic cone of, i. 327.
Chama gigas, growth of, iii. 303.
Chamalières, near Clermont, iv. 160.
Chambon, lake of, how formed, iv. 206.
Chamisso, M., on coral islands, iii. 299.
Chamouni, glaciers of, iv. 61.
Champheix, tertiary red marls of, iv. 161.
Champoleon in the Alps, strata altered near, iv. 376.
Champradelle, vertical marls at, iv. 164.
Charæ, fossilized, iii. 282.
Charlesworth, Mr., on the crag strata, iv. 86.
Chemical changes, whether volcanic heat is produced by, ii. 363.
Chepstow, rise of tides at, ii. 3.
Cheshire, brine springs of, i. 326.
——, waste of coast of, ii. 50.
Chesil bank, ii. 47.
Chesilton, overwhelmed by sea, ii. 48.
Chili, earthquakes in, i. 115.; ii. 231.
——, numerous volcanos in, ii. 93.
——, Newer Pliocene marine strata at great heights in, iv. 31.
Chimborazo, height of, i. 177.
China, climate of, i. 165.
——, earthquakes violent in, ii. 102.
Chines, or narrow ravines, described, ii. 46.
Chittagong, earthquake at, ii. 294.
Chockier, cave at, iii. 233.
Christ Church head promontory, ii. 46.
Christie, Dr. T., on caverns in Sicily, iv. 52, 53. 55.
Christol, M. de, on fossils of Montpellier, iv. 138.
——, on caves, iii. 236, 237.
Cicero cited, i. 41.
Cimbrian deluge, ii. 65.
Cinquefrondi, changes caused by earthquake at, ii. 276.
Ciply, Maestricht beds seen at, iv. 284.
Cirque of Gavarnie, in Pyrenees, iii. 438.
Circular hollows formed by earthquakes, ii. 230. 233. 278, 279.
Cisterna on Etna, how formed, iii. 448.; iv. 30.

Civita Vecchia, springs at, i. 316.
Clarke, Dr., on appearance, &c. of lava in motion, ii. 135.
Clay-slate in Pyrenees, iv. 368.
——, may be altered into shale, and hornblende schist, iv. 382.
Clayton, Bishop, on the deluge, i. 73.
Cleavage, or slaty structure of rocks, iv. 361.
Clermont, sections near, iv. 160. 164. 198.
——, calcareous springs at, i. 308.
Clift, Mr., on bones of animals from Australian caves, iv. 57.
Climate of Europe, Raspe on former, i. 74.
——, change of, in northern hemisphere, i. 135. 138. 159.
——, on causes of vicissitudes in, i. 160.
——, astronomical causes of fluctuations in, i. 219.
——, its influence on distribution of plants, iii. 23.
——, effect of alterations in, on distribution of species, iii. 156. 159. 353.
——, influence of vegetation on, iii. 187.
Climates, insular and excessive, i. 165. ii. 434.
Coal, formation of, at mouths of Mackenzie, iii. 244.
——, reduced to cinder by trap dike, iv. 373.
——. *See* Carboniferous.
Coal formation, fossil plants of the, i. 154. 197. 226. 237.
Cole, Viscount, on delta of the Kander. iv. 83.
Colebrooke, Mr. H. T., on crocodiles of Ganges, i. 358.
Colebrooke, Major R. H., on the Ganges, i. 357.; iii. 192.
Colle, travertin of, i. 309.
——, freshwater formation of, iv. 43.
College, R., transportation of rocks by the, i. 264.
Collini on igneous rocks, i. 85.
Colombia, earthquakes in, ii. 294.
Colonna on organic remains, i. 38.
Comb Hurst, hills of, iv. 226.
Côme lava, current of, iv. 106.
Conception, earthquakes at, ii. 300.; iii. 273.
——, recent fossils at great heights in Bay of, iv. 31.
Conglomerates, tertiary, of Nice, iv. 79.
Conglomerates, now formed by rivers near Nice, iv. 79. 82.
——, volcanic, ii. 196.; iii. 417.
Contemporaneous origin of rocks, how determined, iii. 344.
——, remarks on the term, iii. 385.
Continents, position of former, iv. 314.
Conybeare, Rev. W. D., on Lister, i. 45.
——, on Bristol coal field, i. 200.
——, on earthquakes, ii. 401.
——, on the English crag, iii. 359.
——, on the London clay, iv. 227.
——, on indentations in the chalk, iv. 230.
——, on transverse valleys, iv. 251.
——, on vertical strata of Isle of Wight, iv. 266.
——, on former continuity of chalk of North and South Downs, iv. 257.
——, on theory of M. E. de Beaumont, iv. 340.
Cook, Captain, on drifting of canoes to great distances, iii. 92.
——, on existence of high land near the South Pole, i. 172.
Coomb, ravine called the, near Lewes, iv. 254.
Copernican theory, edicts against repealed at Rome, i. 99.
Copiapo, raised banks of shells at, ii. 233.
Coquimbo, parallel roads of, iv. 32.
Coral between lava currents in West Indies, iii. 315.
Coral islands, iii. 299.
——, beds of oysters, &c., on, in the Pacific, iii. 299.
——, their extent, iii. 301. 316. 320.
——, linear direction of, iii. 302.
——, rate of growth of, iii. 303.
Cordier, M., on rate of increase of heat in mines, ii. 357. 360.
——, his theory of central heat and fluidity, i. 218.; ii. 357.
——, on tides in the internal melted ocean, ii. 362.
Cordilleras shaken by earthquakes, ii. 231. 246.
Corinth, decomposition of rocks in, iii. 152.; iv. 380.
Cornwall, waste of cliffs of, ii. 49.
——, land inundated by drift sand in, iii. 213.
——, temperature of mines in, ii. 356.
——, granite veins of, iv. 347. 374.

Coromandel, inundations of sea on coast of, iii. 220.
Cortesi, i. 78.
Cosmogony distinct from geology, i. 5.
——, of the Hindoos, i. 6.
——, Egyptian, i. 11.
——, of the Koran, i, 30.
Costa de Pujou, hill of, iv. 106.
Costantini, deluge vindicated by, i. 59.
Cotentin, tertiary formation of the, iv. 221.
Cotopaxi, ii. 95. 381.
Coudes, tertiary red sandstone of, iv. 161.
Covelli, M., on increase of temperature of a hot spring in Ischia by earthquake, ii. 230.
Cowper, i. 97.
Couze, R., lake formed by filling up of its ancient bed by lava, iv. 206.
Crag of England, fossils of the, iii. 358.; iv. 85. 87, 88.
——, its age, composition, &c., iv. 85.
——, lacustrine deposits resting on the, iv. 89.
——, stratification of the, iv. 91.
——, compared to Faluns of Touraine, iv. 129, 130.
——, passage of, into alluvium, iv. 100.
——, its resemblance to formations now in progress, iv. 95.
Cramer, Mr., on earthquake of New Madrid, ii. 247.
Crantz, on drift-wood, iii. 246.
Craters of elevation, Von Buch's theory of, considered, ii. 205.
Crawfurd, Mr., his discovery of fossils in Ava, i. 49.
Creation, supposed centres or foci of, iii. 102.
Cremona, lakes filled up near, i. 275.
Creta, argillaceous deposit called, iii. 410. 420. 424.
Cretaceous group, iv. 284.
Crimea, waste of cliffs in the, ii. 64.
Crocodile taken in the Rhone, iii. 71.
Crocodiles imbedded by a river inundation in Java, ii. 304.; iii. 249. 254.
Croizet, M., on extinct quadrupeds of Mont Perrier, iv. 149.
——, on alluviums of Auvergne, iv. 210.
Cromer, waste of cliffs of, ii. 26.
——, section near, iv. 96.
Cropthorn, fossils found at, i. 142.
Crowborough hill, height of, iv. 237.
Crowborough hill, thickness of strata removed from summit of, iv. 272.
Cruckshanks, Mr. A., on earthquake of Chili in 1822, ii. 232.
——, on lines of ancient sea-cliffs on coast of Peru, iv. 32.
Cuckmere, transverse valley of the, iv. 252.
Culver cliff, ii. 44.
Cumana, earthquake of, ii. 251.
Cumberland, slate rocks of, iv. 361. 389.
Cuming, Mr., on earthquake at Valparaiso, 1822, ii. 233.
Currents from equatorial regions, i. 165.
——, from the Pole to the Equator, i. 184.
——, section of débris deposited by opposing, i. 374.
——, causes and velocity of, ii. 3. 7.
——, destroying and transporting power of, ii. 11. 82. 84. 86.
——, in estuaries, their power, ii. 20.
——, in the Straits of Gibraltar, ii. 66.
——, reproductive effects of, ii. 74. 82.
——, on the British shores, ii. 74.
——, distribution of drift-timber by, iii. 247.
Curtis, Mr., on ravages caused by aphides, iii. 114.
Curtis, Mr. John, on power of the tipulæ to cross the sea, iii. 88.
——, on number of British insects, iii. 171.
——, on fossil insects, iii. 249.; iv. 154.
Curves of the Mississippi, i. 279.
Cussac, fossils in alluvium under lava at, iv. 149.
Cutch, changes caused by earthquake of 1819 in, ii. 237.; iii. 273.; iv. 3. 187. 266. 296.
——, map of (see plate 5.) ii. 237.
Cuvier, on durability of bones of men, i. 241.; iii. 265.
——, on variability in species, ii. 435. 438.
——, on identity of Egyptian mummies with living species, ii. 441.
——, on number of fishes, iii. 171.
——, on extinction of the dodo, iii. 134.
——, on oolite fossils, i. 232; iv. 317.
——, on mammiferous remains of the Upper Val d'Arno, iv. 151.
——, on tertiary strata of Paris basin, iii. 354.; iv. 179. 185. 192.
Cuvier, M. F., on aptitude of some animals to domestication, ii. 452.

Cuvier, M. F., on influence of domestication, ii. 458.
Cyclops, island of, in Bay of Trezza, iii. 424.
Cypris fossilized in Scotch marl-lakes, iii. 285.
——, in freshwater strata of Auvergne, iv. 163.
——, habits of living species of (*see figs.*), iv. 163.

D.

Dalman, M., on greywacké rocks of Sweden, iv. 307.
Dangerfield, Captain F., on buried cities in Central India, iii. 216.
Daniell, Professor, on the trade-winds, i. 184.
——, on melting point of iron, ii. 358.
——, on fusion of metals, ii. 360.
——, on deoxidating power of hydrogen, ii. 371.
Danish Archipelago, undermined by currents, ii. 64.
Dante, embankment of rivers noticed by, i. 277.
Dantzic, waste of land near, ii. 64.
D'Anville, M., on gain of land in Red Sea, ii. 80.
Darby, on drift-wood of Mississippi, i. 282.
——, on lakes formed by Red River, i. 286.
——, on marine strata of Lower Louisiana, i. 287.
——, on delta of Mississippi, i. 361.
Darent, transverse valley of the, iv. 251.
Dartmoor granite, iv. 375.
Daubeny, Dr., on mineral springs, i. 305.
——, on country round the Dead Sea, i. 327.
——, on decomposition of trachyte, ii. 91.; iv. 381.
——, on flowing of lava under water, ii. 145.
——, on vicinity of volcanos to the sea, ii. 391.
——, on agency of air and water in volcanos, ii. 393. 395.
——, on nitrogen in mineral springs, iii. 180.
——, on Val di Noto limestone, iii. 409.
——, on eruption of Vesuvius in 1834. iii. 447.
——, on volcanic region of Olot, iv. 104.
Daubeny, Dr., on volcanic district of Lower Rhine and Eifel, iv. 126.
——, on Auvergne volcanos, iv. 213.
D'Aubuisson on Smith's map of England, i. 102.
——, on Auvergne lavas, iii. 445.
Daun, lake-craters near, iv. 117.
Davy, Sir H., on lake of the Solfatara, i. 316.
——, on formation of travertin, i. 317.
——, his theory of progressive development, i. 222.
——, on eruption of Vesuvius, ii. 137.
——, on chemical agency of electricity, ii. 366.
——, his theory of an undoxidated metallic nucleus, ii. 370.
——, on agency of air and water in volcanos, ii. 392. 395.
——, his analysis of peat, iii. 199.
Davy, Dr., on Graham Island, ii. 205. 392.
——, on a helmet taken up from the sea near Corfu, iii. 271.
Davy, Rev. C., on Lisbon earthquake, ii. 295.
Dax, tertiary formations of, iii. 360.; iv. 132.
——, inland cliff near, iv. 136.
Dead Sea, waters of, i. 327.
——, the country around it, volcanic, i. 327.; ii. 106.
De Candolle on hybrid plants, iii. 10.
——, on distribution of plants, iii. 25, 26. 28.
——, on agency of man in dispersion of plants, iii. 43.
——, on stations of plants, iii. 108.
——, on the barriers which separate distinct botanical provinces, iii. 166.
——, on number of land plants, iii. 96.
——, on longevity of trees, iii. 451.
Dee, R., bridge over, swept away by floods, i. 263.
Deer, their powers of swimming, iii. 56.
——, formerly abundant in Scotland, iii. 131.
——, remains of, in marl-lakes, iii. 256.
Deguer on remains of ships, &c. in Dutch peat-mosses, iii. 209.
——, on greywacké fossils, i. 196.
De la Beche, Mr., on delta of Rhone in Lake of Geneva, i. 334.
——, on storm of Nov. 1824, ii. 48.
——, on earthquake of Jamaica, 1692, ii. 308.

De la Beche, Mr., on action of rain in the tropics, iii. 187.
——, on drifting of plants to sea by hurricanes, iii. 247.
——, on coral formations, iii. 310.
——, on alternation of coral and lava in Isle of France, iii. 315.
——, on fossil forest of I. of Portland, iv. 295.
——, on granite of Dartmoor, iv. 375.
De la Hire on fossil wood from Ava, 1692, i. 48.
Delhi territory, elephants in, i. 148.
Delille, on wheat in Egyptian tombs, ii. 442.
——, on native country of wheat, ii. 443.
Delta of the Adige, i. 346.
——, of the Brenta, i. 346.
——, of the Burrampooter, i. 354.
——, of the Ganges, i. 354.
——, its stratification, i. 372.
——, of the Isonzo, i. 346.
——, of the Mississippi, i. 360. 372.
——, of the Niger, size of, iv. 316.
——, of the Nile, i. 349.; iii. 370.
——, of the Po, i. 346.
——, of Rhone, in Lake of Geneva, i. 333.; iii. 368.
——, of Rhone, in Mediterranean, i. 341.
——, of the Tagliamento, i. 346.
Deltas, chronological computations of age of, i. 335.
——, of Lake Superior, i. 338.
——, of the Baltic, i. 340.
——, oceanic, i. 353.
——, grouping of strata in, i. 367.
——, independent in same basin, i. 369.
De Luc, his treatise on geology, 1809. i. 98.
——, on origin of granite, i. 101.
——, on age of deltas, i. 338.
——, on conversion of forests into peat-mosses, iii. 203.
——, on the deluge, iv. 216.
De Luc, M. G. A., his natural chronometers, iii. 210.
Deluge, ancient theories on causes of, i. 31. 45. 52, 53, 54. 56, 57. 59. 73.
——, fossil shells referred to the, i. 33. 56.
Deluge, on changes caused by the, iv. 214.
——, M. de Beaumont on cause of historical, iv. 218.
Deluges part of the present course of Nature, i. 130.
——, local, how caused, i. 288.
——, traditions of different, i. 20. 73.; ii. 104.
Demaillet, speculative views of, ii. 417.
Denudation, effects of, iii. 186. 371. 374.
——, of valley of the Weald, iv. 234.
Deposition of sediment, rate at which the finer kinds subside, ii. 86.
——, shifting of the areas of, iii. 367.
Derbyshire, Whitehurst on, i. 78.
Descartes, iii. 449.
Deshayes, M., on fossil shells, iii. 361. 391. 396. 410. 425,; iv. 37. 43. 85. 144. 154. 188. 285. 290. 334.
——, on subdivisions of the tertiary strata, iii. 388.
——, on limestone of Blaye, iv. 135.
Desjardin, M., bones of the dodo found under lava by, iii. 134.
Desmarest considered geology a branch of physical geography, i. 5.
——, on Auvergne, i. 85.
——, on the separation of England from France, ii. 40.
Desmoulins, M. Ch., on Eocene deposits near Bordeaux, iv. 135.
Desnoyers, M., on human remains in caves, iii. 237.
——, on tertiary formations of Touraine, iii. 360. 388.; iv. 128. 130.
——, on fossils of the Orleannais, iv. 150.
——, on alternation of plastic clay and calcaire grossier in Paris basin, iv. 181.
——, on the Cotentin, iv. 221.
Deucalion's deluge, i. 20.
Didelphis, fossil, in oolite, i. 232.
Dikes, composition and position of, ii. 137.; iii. 412. 414. 440. 444.; iv. 20. 38.
——, how caused, iii. 412.; iv. 21.
——, changes caused by, iii. 414. 441.; iv. 371. 385.
Diluvial theories, iv. 214.
——, waves, whether there are signs of their occurrence on Etna, iii. 454.
——, no signs of, in Campania, iv. 29.
Dimlington height, waste of, ii. 22.
Diodorus Siculus cited, ii. 105. 168.
Dion Cassius cited, ii. 120.
Dodo, recent extinction of the, iii. 133.
Dog, varieties of the, ii. 411. 437.
——, its distinctness from the wolf, ii. 438.
——, hybrids between wolf and, iii. 311.

Dog, examples of acquired instincts hereditary in the, ii. 453.
—— has run wild in America, iii. 136.
Doggerbank, Capt. Hewett on the, ii. 82.
Dollart, formation of estuary of the, ii. 58.
Dolomieu on the Val di Noto, Vicentin, and Tyrol, i. 86.
—— on lavas of Etna, i. 86.
—— on decomposition of granite, i. 329.
—— on earthquake of 1783 in Calabria, ii. 256. 259. 273. 286.
Domestication, aptitude possessed by some animals to, ii. 452. 463.
——, influence of, ii. 457.
Dominica, coral between two lava-currents in, iii. 315.; iv. 36.
Don R., transportation of rocks by, i. 263.
Donati on bed of Adriatic, i. 67. 124. 347.; iii. 295.
Dorsetshire, landslip in, ii. 46.
——, valleys of elevation in, iv. 262.
Doue, M. Bertrand de, on tertiary strata of Velay, iv. 149. 170, 171. 203.
——, on Auvergne alluviums, iv. 210.
Dover, waste of chalk cliffs of, ii. 39.
——, depth of sea near, ii. 39.
——, formation of Straits of, ii. 40.
——, strata at foot of cliffs of, ii. 41.; iv. 274.
Downham buried by blown sand, iii. 213.
Dranse, R., i. 291. 293.
Drift-sand of African deserts, iii. 210.
Drift-wood of Mississippi, i. 280. 283. 361.
——, imbedding of, iii. 241.
——, abundant in North Sea, iii. 246.
Drongs, granitic rocks of Shetland, worn by the sea, ii. 17.
Drontheim, ii. 345.
Druids, their doctrines, i. 26.
Du Bois, M., on tertiary strata of Volhynia and Podolia, iv. 144.
Dufrénoy, M., on the Pyrenees, i. 206.; iv. 375.
——, on limestone of Blaye, near Bordeaux, iv. 135.
——, on hill of Gergovia, iv. 199.
——, on age of red marl and rock-salt of Cardona, iv. 323.
——, on chalk of S. of France, iv. 287.
Dujardin, M. on shells, &c. brought up by artesian well at Tours, i. 303.
Dunes, hills of blown sand, ii. 24. 73.; iv. 94.
Dunwich, destroyed by the sea, ii. 31.
——, crag strata in cliffs near, iv. 89. 93.
Durance, R., land-shells drifted by the, iii. 382.
Dureau de la Malle, M., cited, ii. 437. 452.
Durham, waste of coast of, ii. 21.

E.

Earth, antiquity of the, i. 34.
——, on changes in its axis, i. 52. 56.
——, proportion of land and sea on its surface, i. 216.
——, spheroidal form of the, ii. 352.
——, mean density of the, ii. 355.
——, electric currents in the, ii. 367.
——, sections of the. *See figs.* 45, 46.; ii. 359. 377.
——, effects produced by the powers of vitality on its surface, iii. 175.
Earth's crust, signs of a succession of former changes recognizable in, iii. 325.
——, arrangement of materials composing the, iii. 333.
Earthquakes, energy of, probably uniform, i. 93. 129.
——, earth's surface continually remodelled by, i. 176.
——, all countries liable to slight shocks of, ii. 111.
——, chronologically described, *see* Vol. II. p. 227. *et seq.*
——, phenomena attending, ii. 228.
—— in Cutch, 1819. *See map*, ii. 237.
—— in Calabria, 1783, ii. 254.
——, difficulty of measuring the effects of, ii. 261.
——, chasms formed by, ii, 267, 268.
——, excavation of valleys aided by, ii. 281.; iv. 11.
——, renovating effects of, ii. 397. 402.
——, cause of the wave-like motion of, ii. 379.
——, cause of retreat of sea during, ii. 298.
——, ravages caused by sea during, iii. 220.
——, several thousand people entombed in caverns during, iii. 229.
——, their effects in imbedding cities and forests, iii. 272.
—— in the Pacific, iii. 318.
——, causes of volcanos, and, ii. 350.

East Indian Archipelago, tertiary formations of, iv. 37.
Ecchellensis, Abraham, i. 22.
Edmonston Island, i. 356.
Eels, migrations of, iii. 74.
Egerton, Mr., on delta of the Kander, iv. 83.
Egypt, nearly exempt from earthquakes, i. 14.; ii. 109.
——, cities and towns buried under drift-sand in, iii. 210. 212.
Egyptian cosmogony, i. 11. 244.
—— mummies identical with species still living, ii. 439.
Ehrenberg, M. C. G., found Bengal tiger in Siberia, i. 144.
—— on corals of Red sea, iii. 298, 304. 310. 314. 381.
Ehrenhausen, coralline limestone of, iv. 142.
Eichwald, M., on tertiary deposits of Volhynia and Podolia, iv. 144.
Eifel, volcanos of the, iv. 114. 122.
——, lake-craters of the, iv. 115.
——, trass of the, and its origin, iv. 121.
Electricity, a source of volcanic heat, ii. 366.
——, whence derived, ii. 369.
Elephant, fossil, in India (note), i. 10.
——, in ice on shores of North Sea, i. 79.
"Elephant Bed" at Brighton, ii. 41.; iv. 274. 280.
Elephants covered with hair in Delhi, i. 148.
——, their sagacity not attributable to their intercourse with man, ii. 462.
——, their powers of swimming, iii. 54.
Elevation of land, how caused, i. 49.; ii. 231. 259. 300. 383.; iv. 4.
——, proofs of successive, iv. 8.
Elevation and subsidence, proportion of, ii. 400.
Elevation craters, Von Buch's theory of, considered, ii. 205.
——, origin of the deep gorge in, ii. 221.
Elizabeth or Henderson's Island described, iii. 316.
Elsa, travertin formed by the, i. 308.
——, freshwater formations of the, iv. 42.
Embankment, system of, in Italy, i. 276.
——, gain of land in Adriatic more rapid in consequence of, i. 347.
Emu in Australia will become exterminated, iii. 133.
Engelhardt on the Caspian Sea, ii. 103.; iii. 148.
England, waste of cliffs on coast of, ii. 21. 43.
——, slight shocks of earthquakes felt in, ii. 111. 348.
——, height of tides on east coast of, ii. 2. 29.
——, tertiary strata of, iii. 357, 358.; iv. 39. 85. 224.
——, excavation of valleys in S.E. of, iv. 276.
——, geological map of S.E. of, iv. 233.
Enza, R., iv. 8.
Eocene period, derivation of the term, iii. 392.
——, fossils of the, iii. 393. 395.
——, freshwater formations of, iv. 156.
——, marine formations of, iv. 177.
——, physical geography, fauna and flora of the, iv. 194.
——, volcanic rocks of, iv. 197.
——, map of principal tertiary basins of, iv. 222.
——, alluviums of, iv. 276.
——, chasm between secondary formations and those of, iv. 290.
——, hypogene rocks formed since, iv. 396.
Epomeo, Monte, height, &c., iv. 26.
——, shells in tuff near summit of, iv. 27.
Equatorial current, i. 166.
Equinoxes, precession of the, i. 174.
Erhebungs crater, theory of, considered, ii. 206.
Erie, lake, rapidly filling up, i. 274.
——, peninsula cut through by, ii. 64.
Erman, M., on specific gravity of sea-water, i. 168.
Erratic blocks, of the Alps, iv. 59.
——, transported by ice, i. 265.; iv. 61.
Eruptions, volcanic, number of, per year, ii. 224.
——, cause of, ii. 385.
Erzgebirge, mica slate of the, i. 83.
Escarpments, manner in which sea destroys successive lines of, iv. 8. 242.
——, of chalk in Weald valley, once sea cliffs, iv. 240, 241.
Escher, M., on flood in valley of Bagnes, i. 292.
Eschscholtz Bay, fossils of, i. 149.

Escrinet, Pass of, conglomerate forming at, iii. 232.
Essex, inroads of sea on coast of, ii. 35.
Estuary deposits, arrangement of, iii. 334.
Estuaries described, ii. 20.
——, new ones formed by sea in Holland, ii. 58.
——, how kept open, ii. 75.
——, tides in, ii. 76.
——, gain of land in, does not compensate loss of coast, ii. 77.
——, imbedding of freshwater species in, iii. 285.
Etampes, fossil bones near, i. 96.
Eternity of the earth, or of present system of changes, *not* assumed in this work, iv. 399.
Etna, description of, ii. 123. 164.; iii. 420. 430. 444.
——, lavas of, i. 269. 367.
——, minor volcanos on, ii. 166.
——, buried cones on flanks of, ii. 167.; iii. 438.
——, eruptions of, ii. 168. 174.; iii. 433.
——, towns overflowed by lava of, ii. 171.; iii. 215.
——, subterranean caverns on, ii. 173.
——, great floods on, ii. 176.
——, glacier under lava on, ii. 177.
——, its cone truncated in 1444, ii. 216.
——, said to be an ancient crater of elevation, ii. 221.
——, marine formations at its base, ii. 218.; iii. 420. 424.
——, great valley on east side of, iii. 430.
——, form, composition, and origin of the dikes on, iii. 440.
——, subsidences on, iii. 447.
——, antiquity of cone of, iii. 449.
——, whether signs of diluvial waves are observable on, iii. 454.
Euganean Hills, ancient lavas of, ii. 112.
Europe, newest tertiary strata of, iii. 361.
——, geological map of (*see* plate 2.), i. 209.
——, large portions of, submerged when secondary strata formed, iii. 363.
European tertiary strata, successive origin of, iii. 357.
European alluviums in great part tertiary, iv. 58.
Euxine burst its barrier, according to Strabo, i. 24.
Euxine, gradually filling up, i. 24.
——, *see* Black Sea.
Evaporation, quantity of water carried off by, i. 347.; ii. 62. 67.
——, currents caused by, ii. 7.
Everest, Mr., on island of Munkholm, ii. 345.
Everest, Rev. R., on climate of fossil elephant, i. 148.
——, on sediment of Ganges, i. 363.
Excavation of valleys, ii. 281.; iv. 276.
Extinction of species, successive, part of the economy of nature, iii. 155. 164.
Eyderstede overwhelmed by sea, ii. 65.

F.

Fabio Colonna, i. 38.
Facial angle, iii. 15.
Fair Island, action of the sea on, ii. 18.
Falconi on elevation of coast of Bay of Baiæ, ii. 326.
Falloppio on fossils, i. 35.
Falls of Niagara, i. 271.
—— of St. Mary, only outlet to Lake Superior, i. 339.
Faluns of Touraine, iv. 128.
——, compared to the English crag, iv. 129, 130.
——, how formed, iv. 130.
——, fossils of, iv. 129. 132.
Faraday, Mr., on water of the Geysers, i. 324.
——, on slow deposition of sulphate of baryta powder, ii. 87.
——, on electric currents in the earth, ii. 368.
——, on metallic reduction by Voltaic agency, ii. 371.
——, on liquefaction of gases, ii. 381.
——, experiments of, on carbonate of lime, iv. 373.
Faroe islands, deposits forming near the, iii. 295.
Farquharson, Rev. J., on floods in Scotland, i. 263.
Fasano, marine strata near, iii. 424.
Faujas on Velay and Vivarais, 1779, i. 85.
Ferishta, i. 9.
Ferrara on lavas of Etna, i. 367.
—— on floods on Etna, ii. 177.
—— on earthquake in Sicily, ii. 252.
Ferruginous springs, i. 326.

Férussac, on distribution of freshwater molluscs, iii. 77.
Fetlar, effect of lightning on rocks of, ii. 14.
Fez, earthquakes in, ii. 109.
Fife, coast of, submarine forests on, ii. 20.
——, encroachments of sea on, ii. 21.
Findhorn, old town of, swept away by sea, ii. 19.
Finochio, rock of, iii. 443.
Firestone of Weald Valley, iv. 235.
——, terrace formed by, iv. 242.
Fish, their geographical distribution, iii. 73.
——, migrations of, iii. 74.
—— fossil, i. 230.; iii. 295. 380.
Fissures, sulphur, &c. ejected by, ii. 252.
—— caused by earthquake of 1783 in Calabria, ii. 262. 266. 268.
——, cause of the opening and closing of, ii. 265.
——, preservation of organic remains in, iii. 223.
Fitton, Dr., on history of English geology, i. 72.
——, on Island of Timor, iv. 40.
——, on valley of the Weald, iv. 235. 238. 244. 265. 292, 293, 294.
——, on a line of vertical and inclined strata from I. of Wight to Boulogne, iv. 273.
——, on Maestricht beds, iv. 285. 286.
——, on delta of Niger, iv. 316.
Fiume Salso, in Sicily, iv. 191.
Flagstones and slates, difference between, iv. 362.
Flamborough Head washed into caves, ii. 22.
Fleming, Dr., on uniformity in climate, i. 137.
——, on food of fossil elephant, i. 143.
——, on submarine forests, ii. 20.; iii. 275.
——, on rapid flight of birds, iii. 69.
——, on turtles taken on coast of England, iii. 69.
——, on changes in the animal kingdom caused by man, iii. 130.
——, on stranding of cetacea, iii. 289.
——, on fossils of the crag, iv. 101.
——, on effects of the deluge, iv. 217.
Flinders on coral reefs, iii. 298. 301. 312.
Flint on course of Mississippi, &c., i. 278. 281.
Flint on earthquakes in Mississippi valley, ii. 247.
Flood, supposed effects of the, iv. 214.
——, hypothesis of a partial, iv. 214.
Floods, bursting of lakes, &c., i. 288.
—— in North America, i. 289.
—— in valley of Bagnes, i. 291.
—— in Scotland, i. 262.; iii. 253.
—— at Tivoli, i, 294.
—— on Etna, ii. 177.
Floridia, limestone of, iii. 409.
Fluvia, R., ravines in lava excavated by, iv. 106. 110.
Foah, advance of delta of Nile near, i. 350.
Folkestone, subsidence of land at, ii. 41.
Fontenelle, his eulogy on Palissy, i. 38.
Forbes, Mr., on Bay of Baiæ, ii. 322.
——, on temple of Serapis, ii. 324.
Forest ridge of Weald valley, iv. 244.
——, faults in strata of the, iv. 244.
——, thickness of masses removed from the, iv. 272.
Forests, influence of, iii. 185. 187. 190.
——, sites of, now covered by peat, iii. 202.
——, destroyed by insects, iii. 195.
——, submarine, ii. 20.; iii. 274.
Forfarshire, encroachments of sea on coast of, ii. 19.
——, marl-lakes of, iii. 282. 322.
——, composition of secondary rocks of, iv. 384.
Forio, earthquake near, ii. 230.
Formosa, earthquakes in, ii. 100.
Forster, Mr., on coral reefs, iii. 298.
Forsyth on climate of Italy, ii. 163.
Fortis on Arabian doctrine of new genera and species, i. 23.
——, views of Arduino confirmed by, i. 84.
—— and Testa on fossil fish of Monte Bolca, i. 77.
Fossa Grande, section of Vesuvius seen in, iii. 433.
Fossilization of organic remains on emerged land, iii. 199.
—— in peat mosses, iii. 204.
—— in caves and fissures, iii. 223.
—— in alluvium and landslips, iii. 219.
—— in volcanic formations on land, iii. 213.
—— in subaqueous deposits, iii. 240. 258.
—— by river floods, iii. 251.
—— in marl lakes, iii. 256.

Fossilization of plants and animals partial, iii. 372.
Fossils, speculations concerning their nature, i. 41. 44, 45.
——, formerly all referred to the deluge, i. 42.
—— of the coal strata, i. 154. 196. 226.
——, distinctness of secondary and tertiary, i. 206.; iv. 290.
——, mammiferous of successive tertiary eras, iii. 401.
——. *See* Organic remains.
Fourier, Baron, on temperature of spaces surrounding our atmosphere, i. 187.
——, on central heat, i. 217.
——, on radiation of heat, i. 218.
Fournet, M., on alluvium in ancient fissures, iv. 211.
——, on disintegration of rocks, iv. 380.
——, on mineral veins, iv. 382.
Fox, Mr., on heat in mines, ii. 356.
——, on electric currents in the earth, ii. 367.
France, waste of coast of, ii. 50.
——, caves of, iii. 235.
Franconia, caves of, iii. 232.
Frankfort, tertiary strata near, iv. 145.
Franklin, on a whirlwind in Maryland, iii. 32.
Freshwater formations, species of testacea few in, iii. 288.
——, secondary, why rare, iv. 320.
Freshwater plants and animals fossilized, iii. 281. 285.
Freyberg, school of, i. 91.
Fries, on dispersion of cryptogamic plants, iii. 34.
Frisi on influence of vegetation, iii. 185.
Fryer, Mr., on earthquake in Chili, ii. 233.
——, on Isle of San Lorenzo, ii. 303.
Fuchsel, opinions of, 1762, i. 75.
Funchal, rise of sea during earthquake at, ii. 298.
Fuveau, in Provence, tertiary strata of, iv. 223.

G.

Gabel Tor, volcano of, ii. 110.; iv. 40.
Galieri, a bed of corals among igneous formations at, iii. 418.
Gambier coral island, iii. 312.
Ganges, delta of the, i. 354. 372.
——, its ancient mouths, i. 354.
——, inundations of the, i. 359.; iii. 254.
——, quantity of sediment in waters of, i. 363.
—— and Burrampooter not yet completely united, i. 372.
——, islands formed by the, iii. 192.
——, bones of men found in delta of, iii. 265.
Gannat, freshwater limestone of, iv. 165.
Garachico, in Teneriffe, overwhelmed by lava, ii. 304.
Gardner, on destruction of Dunwich by the sea, ii. 31.
Gardner, Mr., cited, i. 172. 216.
Garnets, in altered shale, iv. 371.
Garrinada, hill of, iv. 106.
Gases, liquefaction of, ii. 381.
——, evolved by volcanos, ii. 392.
——, passage of through rocks, iv. 379.
Gaulish Druids, i. 26.
Gault of Weald Valley, iv. 235.
——, valley formed at its out-crop, iv. 243.
Gavarnie, cirque of, iii. 438.
——, lamination of clay-slate near, iv. 368.
Gay-Lussac, M., on the vibration of solid bodies, ii. 381.
——, on agency of water in volcanos, ii. 392.
Gefle, upraised shelly deposit near, ii. 342. 344.
Gemmellaro, on eruption of Etna in 1811, ii. 174.
——, on ice under lava, ii. 177.
Gemunder Maar, view of, iv. 117.
Generation, spontaneous, theory of, i. 37.
Generelli, on state of geology in Europe in middle of 18th century, i. 61.
——, on effects of earthquakes in recent times, i. 64, 65. 92.
Geneva, lake of, men drowned above Martigny floated into, i. 292.
——, delta of Rhone in, i. 333. 368.; iii. 368.
Genoa, tertiary strata at, iv. 77.
Geognosy of Werner, i. 80.
Geographical distribution of plants, iii. 24.
—— of animals, iii. 48. 54.
—— of birds, iii. 66.
—— of reptiles, iii. 70.
—— of fishes, iii. 73.

Geographical distribution of testacea, iii. 76.
—— of zoophytes, iii. 82.
—— of insects, iii. 83.
—— of man, iii. 89.
Geography, proofs of former changes in physical, i. 194. 209.
——, effect of changes in, on species, iii. 144.
Geological Society of London, i. 103.
Geological theories, causes of error in, i. 109.
Geology defined, i. 1.
—— compared to history, i. 1.
——, its relation to other physical sciences. i. 2.
—— distinct from cosmogony, i. 5.
—— considered by Werner as part of mineralogy, i. 5.
——, causes of its retardation, i. 41. 96. 109.
——, state of, in Europe, before middle of last century. i. 62.
——, modern progress of, i. 103.
Georges Gemund, freshwater strata of, iv. 145.
Georgia, in island of, perpetual snow to level of sea, i. 171. 188.
Gerbanites, an Arabian sect, their doctrines, i. 23.
Gergovia, section of hill of, iv. 199.
German Ocean, filling up, ii. 81.
Gesner, John, on organic remains, i. 70.
Geysers of Iceland, i. 324. ; ii. 386.
——, cause of their intermittent action, ii. 388.
Giacomo, St., valley of, described, iii. 434, 435. 442.
Gian Greco, fall of cliffs during earthquake, ii. 279.
Gibraltar, birds' bones in breccia at, iii. 231.
——, Straits of, ii. 66.
——, supposed under-current in, ii. 67.
Gillenfeld, Pulvermaar of, iv. 118.
Girard, M., on mud of the Nile, i. 351.
—— on former union of Mediterranean and Red Sea, ii. 83.
Girgenti, tertiary strata at, iii. 407. 419.
Gironde, tides in its estuary, ii. 76.
——, tertiary strata of basin of, iv. 132.
Glacier, under lava, on Etna, ii. 177.
Glaciers, formation of, i. 152. 265.
—— of Spitzbergen, i. 168.
——, transportation of rocks by, i. 265. ; iv. 61.
Glen Roy, parallel roads of, iv. 33.
Glen Tilt, granite veins of, i. 89.
——, junction of limestone and granite in, iv. 347.
Gloger, M., cited, iii. 96.
Gloucestershire, gain of land in, ii. 50.
Gly, R., tertiary strata, in valley of the, iv. 83.
Gmelin on distribution of fish, iii. 75.
Gneiss, mineral composition of, iv. 367. 369.
——, passage of, into granite, iv. 369. 377.
——, whence derived, iv. 369. 382.
Goats, multiplication of, in South America, iii. 137.
Godman on migrations of rein-deer, iii. 62.
Golden age, doctrine whence derived, i. 13.
Goldfuss, Professor, on the greywacké, iv. 306.
Goodwin Sands, ii. 38.
Goree on new island, ii. 209.
Gothenburg, rise of land near, ii. 341.
Gozzo degli Martiri, dikes at, iii. 412.
——, view of valley of, iv. 7.
Graah, M., on subsidence of Greenland, ii. 346.
Graham, Mrs., on earthquake of Chili in 1822, ii. 235.
Graham Island, ii. 199.; iii. 415.
——, views of, *see* wood-cuts, ii. 201, 202.
——, depth of sea from which it rose, ii. 199.
——, arrangement of the ejected materials on, ii. 201.
Grammichele, strata near, iii. 409.
——, bones of mammoth in alluvium at, iv. 62.
Grampians, granite veins of the, iv. 349.
Granada, tertiary strata of, iv. 84.
Granite of the Hartz, greywacké slate with organic remains found in, i. 83.
——, disintegration of, in Auvergne, i. 329.
——, junction of limestone and, in Glen Tilt, iv. 347.
——, formed at different periods, iii. 339. ; iv. 350.
——, passage from trap into, iv. 355.
——, origin of, iii. 358. ; iv. 357.
——, passage of gneiss into, iv. 369. 377.
——, changes produced by its contact

with strata of lias and oolite in the Alps, iv. 376.
Granite, veins, their various forms and mineral composition, i. 89. ; iv. 345. 374.
Graves, Lieut., on diffusion of insects by the wind, iii. 87.
Graves, Mr., on distribution of the bustard, iii. 132.
Graves, M., on Valley of Bray, iv. 297.
Gravesend, indentations in chalk filled with sand, &c., near, iv. 230.
Grecian Archipelago, new isles of the, i. 75.
——, volcanos of the, ii. 109.
——, chart and section of, ii. 207.
Greece, earthquakes in, iii. 229.
Greenland, why colder than Lapland, i. 164.
——, sometimes shaken by earthquakes, ii. 110.
——, gradual subsidence of, ii. 346. 384.
——, timber drifted to shores of, iii. 246.
Greenough, Mr., on fossil shells from borders of Red Sea, iv. 40.
Greville, Dr., on drift sea-weed, iii. 37.
Greywacké formations, extent of, i. 292.
——, fossils of, i. 195.
——, of the Eifel, iv. 115.
——, classification of the, iv. 305.
Grifone, Monte, caves in, iv. 53.
Grimaldi, on earthquake of 1783 in Calabria, ii. 255. 268. 271.
Grind of the Navir, passage forced by sea in Shetland islands, ii. 15.
Grosœil, tertiary strata at, iv. 39.
Grosse, Dr., on baths of San Filippo, i. 312.
Grotto del Cane, i. 328.
Guadaloupe, human skeletons of, iii. 265.
——, volcanos in, iv. 36.
Guatimala, active volcanos in, ii. 97.
——, town of, swallowed up by earthquakes, ii. 292.
Guettard on the Vivarais, i. 85.
Guiana, its maritime district formed by sediment of the Amazon, ii. 85.
Guidotti, Signor, on Subapennine fossils, iii. 386.
——, on shells in gypsum of Monte Cerio, iv. 68.
Guilding, Rev. L., on migration of boa constrictor, iii. 72.
Guinea current, ii.
Güldenstädt, on distinctness of the dog and wolf, ii. 438.
Gulf stream, i. 166. ; ii. 5. 11. ; iii. 35.
Gulholmen, island of, gradually rising, ii. 341.
Gun-barrel, with shells attached, found in sands, iii. 270.
Gunnell, Mr., on loss of land in Sheppey, ii. 36.
Gypsum and marls of Paris basin, iv. 184.
——, bones of quadrupeds, &c., in, iv. 190.
——, of St. Romain on the Allier, iv. 167.
——, Subapennine, iv. 68.
Gyrogonite described, iii. 282.

H.

Habitations of plants described, iii. 25.
Hall, Sir J., his experiments on rocks, i. 89. ; iv. 24.
Hall, Capt. B., on Falls of Niagara, i. 271.
——, on width of Mississippi, i. 278.
——, on islands in Mississippi, i. 280.
——, on drift-wood in Mississippi, i. 283. 361.
——, on flood in valley of Bagnes, i. 292.
——, on the trade winds, ii. 8.
——, on volcanic eruption in Tierra del Fuego, ii. 93.
——, on temple of Serapis, ii. 319.
——, on isle of Cyclops, iii. 426.
——, on parallel roads of Coquimbo, iv. 32.
——, on dikes in Madeira, iv. 38.
——, on veins in the Table Mountain, Cape of Good Hope, iv. 346.
Hall, Mr. J., on temple of Serapis, ii. 319.
Hallstrom, Col., on rise of land in gulf of Bothnia, ii. 335.
Hamilton, Sir W., on mass covering Herculaneum, ii. 151.
——, on earthquake of 1783, in Calabria, ii. 256. 273. 275.
Hamilton, Sir W., on earthquakes attending the eruption of Monte Nuovo, ii. 326.
——, on eruption of Vesuvius in 1779, ii. 134. ; iv. 22.
Hamilton, Sir Charles, on submerged buildings of Port Royal, iii. 278.

Hampshire, Brander on fossils of, i. 76.
——, submarine forest on coast of, iii. 276.
——, tertiary formations of, iii. 357.; iv. 224. 228, 229.
——, on former continuity of the basins of London and, iv. 232.
Happisborough, submarine forest of, iii. 274.
——, crag strata near, iv. 92.
Harcourt, Rev. W. V. V., on bones of mammoth, &c. in Yorkshire, i. 142.
Harlbucht bay, ii. 59.
Harris, Hon. C., on sunk vessel off Poole harbour, iii. 266.
——, on a submarine forest on coast of Hampshire, iii. 276.
Hartmann, Dr., on greywacké fossils in granite of the Hartz, i. 83.
Hartsoeker on sediment in waters of Rhine, i. 362.
Hartz mountains, i. 83.; iv. 339.
Harwich, waste of cliffs at, ii. 35.
Hastings sands, their composition, iv. 235.
——, anticlinal axis formed by, iv. 238.
Hatfield moss, trees found in, iii. 202.
Haute Loire, freshwater formation, iv. 170.
Headen Hill, section of, iv. 229.
Heat, laws which govern the diffusion of, i. 162.
——, its influence on consolidation of strata, iv. 324.
Heber, Bishop, on animals inhabiting the Himalaya mountains, i. 148.
Hebrides, volcanic rocks of the, iv. 326.
Hecla, columnar basalt of, i. 84.
——, eruptions of, ii. 179.
Heidelberg, loess and gravel alternating at, iv. 45.
——, granites of different ages near, iv. 349.
Heilbronn, loess of, iv. 49.
Helice and Bura, submerged Grecian towns, ii. 108.; iii. 278.
Heligoland destroyed by sea, ii. 58.
Helix, range of species of, iii. 78.
Helmet, changes of submerged, iii. 271.
Henderson on eruption of Skaptar Jokul, 1783, ii. 180.
Henderson's Island described, iii. 316.
Henry, Mr., on absorption of carbonic acid by water, iv. 379.
Henslow, Rev. Prof., on the cowslip, ii. 447.
Henslow, Rev. Prof., on diffusion of plants, iii. 40.
——, on changes caused by a dike in Anglesea, iv. 371. 385.
Herbert, Hon. Mr., on varieties and hybrids in plants, ii. 447.; iii. 10.
Herculaneum, silence of contemporary historians concerning, ii. 119.
——, how destroyed, ii. 147.
——, objects preserved in, ii. 152. 157.
——, stalactite formed in galleries of, ii. 153.
Herne Bay, waste of cliffs in, ii. 35.
Herodotus cited, i. 349. 351.
Herschel, Sir J., on annual quantity of light and heat received by the two hemispheres, i. 174.
——, on the sun, i. 219.
——, on astronomical causes of changes in climate, i. 219.
——, on the trade winds, ii. 11.
——, on height of Etna, ii. 164.
——, on the lunar mountains, ii. 222.
——, on form of the earth, ii. 352.
——, on Geysers of Iceland, ii. 388.
Herschel, Sir W., on the elementary matter of the earth, ii. 351.
Hewett, Capt., on rise of tides, ii. 3.
——, on currents, ii. 6.
——, on banks in North Sea, ii. 81.
Hibbert, Dr., on the Shetland Islands, ii. 13, 14. 16.
——, on Rhine volcanos, iv. 119.
——, on loess of the Rhine, iv. 48. 51.
——, on fossils of Velay, iv. 149.
——, on freshwater deposits in the coal strata, i. 198. 230.; iv. 302.
Hiera, new island, ii. 208.
Highbeach, height of London clay at, iv. 270.
Hilaire, M. Geof. St., on uninterrupted succession in animal kingdom, ii. 406.
Hillswick Ness, action of sea on rocks of, ii. 17.
Himalaya mountains, animals inhabiting the, i. 148.
——, height of perpetual snow on, i. 190.
Hindoo cosmogony, i. 6.
Hindoo town, buried, iii. 221.
Hindostan, earthquakes in, ii. 110. 294.
Hisinger, M., on greywacké rocks of Sweden, iv. 307.
Hodgson, Mr., cited, i. 144.
Hoff, Von, on level of Caspian, i. 29.
——, on Omar, i. 30.
——, on springs near Lake Urmia, i. 322.

Hoff, Von, on encroachments of sea, ii. 61. 64.
——, on gain of land in Red Sea, ii. 80.
——, on earthquakes, ii. 106. 230. 293.
——, on buried city of Oojain, ii. 242.
——, on human remains in delta of Ganges, iii. 265.
——, on a buried vessel, iii. 267.
Hoffmann, M., on new island in Mediterranean, ii. 200.; iii. 415.
——, on elevation craters, ii. 222.
——, on Sicily, iii. 412.; iv. 52. 54.
——, on agency of subterranean gases, iv. 380.
Holbach, his theory, 1753, i. 57.
Holderness, marine strata of, iv. 88.
Holland, inroads of the sea in, ii. 55.
——, submarine peat in, iii. 288.
Holm sand, near Lowestoff, ii. 30.
Homer, cited, i. 350.
Honduras, recent strata of, iv. 37.
Hooke, his "Discourse of Earthquakes," i. 46.
—— on distribution and duration of species, i. 47, 48.
—— on earthquakes, i. 50.; ii. 302. 305. 327.
—— on the deluge, i. 50.
Hooker, Dr., on eruption of Skaptar Jokul, ii. 180.
——, his view of the crater of the great Geyser, ii. 387.
——, on drifting of a fox on ice, iii. 126.
Hordwell, loss of land at, ii. 45.
Hornblende schist, altered clay or shale, iv. 383.
Horner, Mr., on sediment of Rhine, i. 362.; iv. 47.
——, on geology of Lower Rhine and Eifel, iv. 115. 124.
Hornitos, on Jorullo, account of, ii. 188.
Horsburgh, Capt., on icebergs in low latitudes, i. 173.
——, on delta of Ganges, i. 356.
——, on coral islands, iii. 302. 312.
Horses, wild, drowned in rivers in South America, iii. 253.
Horsfield, Dr., on earthquakes and eruptions in Java, ii. 252. 293.
——, on distribution of Mydaus meliceps in Java, iii. 60.
Horticulture, changes in plants produced by, ii. 443.
Hugi, M., on altered secondary strata in the Alps, iv. 377.
——, on modern granite in the Alps, iv. 351
Human remains, changes in buried, iii. 236.
——, in peat-mosses, iii. 205.
——, in caves, iii. 227. 229. 234.
——, their durability, i. 241.; iii. 265.
—— in delta of Ganges, iii. 265.
—— in calcareous rock at Guadaloupe, iii. 265.
—— in breccias in the Morea, iii. 227.
Humber, warp of the, i. 373.; ii. 79.
——, encroachment of sea in its estuary, ii. 23.
Humboldt on laws which regulate the diffusion of heat, i. 162.
—— on distribution of land and sea, i. 189.
—— on transportation of sediment by currents, ii. 85.
——, his definition of volcanic action, ii. 91.
—— on mud eruptions in the Andes, ii. 96.
—— on eruption of Jorullo, ii. 187.
—— on earthquakes, ii. 246. 251. 253.
—— on distribution of species, iii. 24. 26. 50.
—— on migrations of animals, iii. 69. 86. 134.
—— on Teneriffe, ii. 304.
—— on the depression of a large part of Asia, below the level of the sea, iii. 371.
——, cited, i. 10. 144. 169.
Humming-birds, distribution, &c. iii. 67.
Hungary, tertiary formations of, iv. 141. 144.
——, volcanic rocks of, iv. 153.
Hunstanton, its cliffs undermined, ii. 24.
Hunter, John, on mule animals, iii. 2.
Hunter, Mr., on buried city of Oujein, iii. 215.
Huron, Lake, recent strata of, iii. 285.
Hurricanes connected with earthquakes, iii. 220.
——, plants drifted to sea by, iii. 247.
Hurst Castle shingle bank, ii. 45.
Hutchins on a landslip in Dorsetshire, ii. 46.
Hutchinson, John, his "Moses's Principia," 1724, i. 57.
——, on Woodward's theory, i. 57.
Hutton, first to distinguish between geology and cosmology, i. 5. 88.
—— on igneous rocks, i, 89.
—— on granite, i. 89.

Hutton represented oldest rocks as derivatives, i. 91.; iv. 398.
Hutton, Mr. W., on fossil plants of the coal strata, i. 197. 226.
——, on freshwater strata of the coal period, iv. 302.
Huttonian theory, i. 88. 91. 94. 100.
Hybrid races, Lamarck on, ii. 416.
—— animals, iii. 1.
—— plants, iii. 5.
Hydrogen, deoxidating power of, ii. 371.
——, why not found in a separate form among volcanic gases, ii. 392.
Hydrophytes, distribution of, iii. 29. 36.
Hypogene, term proposed as a substitute for primary, iv. 385.
—— formations, no order of succession in, iv. 387.
—— rocks, their identity of character in distant regions, iv. 388.
—— produced in all ages in equal quantities, iv. 390.
——, their relative age, iv. 390.
——, volume of, formed since Eocene period, iv. 396.
Hythe, encroachments of sea at, ii. 42.

I.

Ianthina fragilis, its range, &c., iii. 77.
Ice, animals imbedded in, i. 152.
——, predominance of, in Antarctic circle, i. 170.
——, formation of field, i. 186.
——, transportation of rocks by means of, i. 265.; ii. 334.; iv. 60, 61.
——, jointed structure of, iv. 366.
Icebergs, formation of, i. 152. 168.
——, distance to which they float, i. 173. 267.
——, plants and animals transported by, iii. 36. 61.
——, rocks transported by, i. 266.; ii. 334.; iv. 60, 61.
Iceland, geysers of, i. 324.; ii. 386.
——, volcanic region of, ii. 110.
——, volcanic eruptions in, ii. 179.
——, comparison between the lavas of Central France and, ii. 182.
——, new island near, ii. 180. 198.
——, elevation and subsidence in, ii. 304.
——, polar bear drifted to, iii. 124.
Idienne, volcanic mountain of, iv. 191.
Igloolik, fossils of, i. 159.
Igneous action. *See* Volcanic.
Igneous causes. *See* Book ii.
——, the antagonist power to action of running water, i. 255.; ii. 398.; iii. 183.
Iguanodon, fossil in Wealden and Kentish rag, iv. 297.
Imbaburu volcano, fish ejected from, ii. 96.
Imbedding of organic remains. *See* Fossilization.
Imperati, theory of, 1590, i. 38.
India, Central, buried cities in, iii. 215.
Indus, recent changes in delta of, ii. 237.; iii. 274. 288.
——, sections of the new-raised land formed by, ii. 240.
Indusial limestone of Auvergne, iv. 165.
Inkpen Hill, highest chalk in England, iv. 272.
Inland cliff, near Dax, iv. 136.
——, on east side of Val di Noto, iv. 8.
Inland seas, deltas of, i. 340.
Insects, geographical distribution of, iii. 83.
——, migrations of, iii. 84.
——, certain types of, distinguish particular countries, iii. 85.
——, their agency in preserving an equilibrium of species, iii. 110.
——, fossil, iii. 249.; iv. 223.
Instincts, migratory, occasional development of, in animals, iii. 57.
——, hereditary, ii. 453. 459.
——, modified by domestication, ii. 457.
Insular climates, description of, i. 165.
Inverness-shire, inroads of sea on coast of, ii. 19.
Ionian Isles, earthquake in, ii. 237.
——, new island near, ii. 237.
Ippolito, Count, on earthquake of 1783, in Calabria, ii. 256.
Ipsambul, buried temple of, iii. 211.
Irawadi, R., silicified wood of, noticed in 1692, i. 48.
——, recent discoveries of fossil animals and vegetables, i. 48.
——, its supposed petrifying power, i. 325.
Ireland, rise of sea, during Lisbon earthquake, on coast of, ii. 298.
——, reptiles of, iii. 71.
——, its flora little known, iii. 71.
——, peat of, and fossils of peat in, iii. 200. 205. 207.
——, deposits in progress off coast of, iii. 294.

Ireland, rocks altered by dikes in, iv. 373.
Iron, melting point of, ii. 358.
—— in wood, peat, &c., iii. 204.
—— instruments, taken up from sea, iii. 269.
Irtish, R., fossil bones on banks of, i. 145.
Irving, Mr. W., on migrations of the bee, iii. 86.
Ischia, recent fossils of, i. 137, ; iv. 26.
——, hot springs of, i. 325. ; ii. 230.
——, eruptions and earthquakes in, ii. 114. 122. 230.
——, volcanic conglomerates forming on shores of, iii. 417.
——, configuration of, how caused, iii. 319. ; iv. 27.
Islands, vegetation of small, i. 191. ; iii. 27. 102.
——, animals in, i. 199. ; iii. 52.
——, in the Mississippi, i. 280.
——, formed by the Ganges, i. 356, 357.
——, migrations of plants aided by, iii. 36.
——, new volcanic, i. 75. ; ii. 180. 198, 199. 248. 295.
——, coral, iii. 298.
——, of drift-wood, iii. 62.
Isle of Bourbon, volcanic eruptions in, iv. 357.
Isle of Cyclops, in bay of Trezza, iii. 424.
——, contortions in strata of, iii. 426.
——, lavas of, not currents from Etna, iii. 428.
—— of France, alternation of coral and lava in, iii. 315.
—— of Palma, description of, ii. 213.
—— of Purbeck, line of vertical chalk in, ii. 45. ; iv. 273.
—— of Wight, geology of the, iii. 357.
——, fall of one of the Needles of, iv. 100.
——, freshwater strata of, iv. 228.
——, mammiferous remains of, iv. 229. 276.
——, vertical strata of, iv. 266. 272.
——, action of the sea on its shores, ii. 44.
Izonzo, R., delta of the, i. 346.
——, its present mouth several miles from its ancient bed, i. 348.
——, conglomerate formed by the, i. 348.
Isothermal lines, Humboldt on, i. 162.
Isthmus of Sleswick, action of sea on, iii. 59. 151.
Italian geologists, their priority, i. 38.
—— of the 18th century, i. 58.
Italy, tertiary strata of, i. 58. 138. ; iii. 357. 386.
——, volcanic rocks of, iv. 102.

J.

Jack, Dr., on island of Pulo Nias, iv. 37.
Jackson, Col., on jointed structure of ice, iv. 366.
Jahde, new estuary of, ii. 59.
Jamaica, earthquakes in, ii. 98. 307. 323.
——, subsidence in, ii. 307. ; iii. 146. 272. 278.
——, rain diminished in, by felling of forests, iii. 187.
——, a town swept away by sea in, iii. 221.
——, fossil shells of, iv. 37.
James, Mr., on bisons in Mississippi Valley, iii. 56.
Jampang, village engulphed, ii. 252.
Jan Mayen's Island volcanic, ii. 110.
Japan Isles, earthquake in, ii. 252.
Java, number of volcanos in, ii. 101.
——, earthquakes in, ii. 252. 293.
——, subsidence of volcano of Papandayang in, ii. 293. ; iii. 447.
——, vegetation destroyed by hot sulphuric water from a mountain in, iv. 191.
Java, river-floods in, ii. 304. ; iii. 249. 254.
Jesso, volcanos in island of, ii. 100.
Jobert, M., on extinct quadrupeds of Mont Perrier, iv. 149.
——, on hill of Gergovia, iv. 199.
——, on Auvergne alluviums, iv. 210.
Johnston, Mr., on sinking of the waters of Lake Maeler, ii. 338.
Jointed structure in rocks, iv. 365.
Jones, Sir W., on Menù's Institutes, i. 6.
Jorio, Andrea de, on Temple of Serapis, ii. 319. 325.
Jorullo, eruption of, ii. 97. 186.
——, its height, &c., ii. 187. ; iv. 357.
Juan Fernandez, iii. 137.
Jura, Saussure on the, i. 79.
——, relative age of the, i. 206.
——, erratic blocks of the, iv. 59.
Jutland, its northern part converted for a time into an island in 1825, ii. 59.
——, inundations in, ii. 66.

K.

Kaiserstuhl, volcanic hills in plains of the Rhine, iv. 45.
Kamtschatka, active volcanos in, ii. 99.
——, subsidences and elevations in, ii. 304.
——, new island near, ii. 248.
Kander, R., delta of, in lake of Thun, iv. 82.
Kangaroo giving way in Australia, iii. 133.
Katavothrons of plain of Tripolitza filled up with osseous breccias, iii. 227.
Kazwini on changes in position of land and sea, i. 31.
Keferstein, M., on Fuchsel, i. 75.
Keill refutes Burnet's and Whiston's theories, i. 57.
Keith on dispersion of plants, iii. 34.
Kent, loss of land on coast of, ii. 35.
Kentucky, caves in limestone, iii. 224.
Kerguelen's land, quadrupeds in, i. 199.
Killas of Cornwall, iv. 375.
Kimmeridge clay, ii. 46.
Kincardineshire, village in, washed away by sea, ii. 19.
King, Captain P., on currents in Straits of Magellan, ii. 6.
——, on coral reefs, iii. 301. 313.
King, Mr., on cattle lost in bogs in Ireland, iii. 207.
——, on submerged cannon, iii. 269.
Kingsclere, valley of, iv. 259.
Kinnordy, Loch of, insects in marl in, iii. 249.
——, canoe in peat of, iii. 268.
Kirby, Rev. Mr., on insects, iii. 12. 84. 87. 114. 116.
Kirwan, his Geological Essays, i. 98.
—— on connection of geology and religion, i. 98.
—— on age of deltas, i. 338.
Knight, Mr., on varieties of fruit trees, ii. 445.
Kölreuter on hybrid plants, iii. 5.
König, Mr., on rock in which the human skeletons from Guadaloupe are imbedded, iii. 265.
——, on fossils from Melville Island, i. 155.
Koran, cosmogony of the, i. 30.
Kossa, cited, i. 31.
Kotzebue on drifted canoe, iii. 92.
—— on coral islands, iii. 300.
Krantz on migrations of seals, iii. 66.
Kupffer, M., on increase of heat in mines, ii. 356.
Kured, upraised shelly deposits of, ii. 343.
Kurile Isles, active volcanos in, ii. 100.

L.

Laach, lake-crater of, iv. 119.
Labrador, drift-timber of, iii. 246.
Laccadive Islands, iii. 302.
Lacépède on Egyptian mummies, ii. 441.
Lagoons, or salt lakes in delta of Rhone, i. 344.
—— of coral islands, iii. 310.
Lagullas current, i. 165.
Lahn, valley of the, iv. 46.
Lake Aidat, how formed, iv. 213.
Lake Erie, *see* Erie, lake.
—— of Geneva, *see* Geneva, lake of.
—— Maeler, ii. 338. 345.
—— Mareotis, i. 350.
—— Superior. *See* Superior, lake.
Lakes, bursting of, i. 288. 291.
——, filling up of, i. 333. 336.
—— formed by landslips in Calabria, ii. 277.
——, formation of in basin of Mississippi, i. 286.
—— formed by earthquakes, ii. 247. 269. 277. 308.
——, arrangement of deposits in, iii. 334
L'Altar volcano, ii. 95.
Lamarck, his definition of species, ii. 407.
—— on transmutation of species, ii. 407. 442.; iii. 155. 161.
—— on conversion of the orang-outang into the human species, ii. 421.
—— on abundance of polyps, iii. 171.
—— on fossils of Paris basin, iv. 64.
La Motta, in Sicily, iii. 423. 429.
Lamouroux on hydrophytes, iii. 29.
Lancashire, submarine forests on coasts of, ii. 50.
——, fossil canoes in, iii. 267.
——, tertiary strata of, i. 211.; iv. 39.
Lancerote, volcanic eruptions in, ii. 192. 197.
Land, irregular distribution of, i. 189.
——, quantity of, in northern and southern hemispheres, i. 172. 189.
——, proportion of sea and, i. 216.
——, elevation of, how caused, ii. 383.; iv. 4.

Landers on delta of Niger, iv. 316.
Landes, tertiary strata of the, iv. 136.
Landguard Fort, waste of the point on which it stands, ii. 34.
Land-shells drifted to the sea by rivers, iii. 382.; iv. 47.
Landslips, ii. 47. 272. 274. 276. 308.
—— imbedding of organic remains by, iii. 222.
——, villages and their inhabitants buried by, iii. 222.
Langsdorf on new island, ii. 100. 248.
Languedoc, deposits on coast of, i. 345.
Lapidifying juice, i. 36.
Laplace on change in the earth's axis, i. 56.
—— on mean depth of Atlantic and Pacific Oceans, i. 180.
—— proved that no contraction of the globe had taken place for 2000 years, i. 217.
—— on mean density of the earth, ii. 355.
Lapland, why milder than Greenland, i. 164.
——, migrations of animals in, iii. 57, 58.
Larivière, M., on drifting of rocks by ice, i. 267.
La Roche, section of hill of, iv. 161.
Las Planas, lava current of, iv. 109.
Latham on range of birds, iii. 68.
Latitude influences climate, i. 171.
Latreille on distribution of insects, iii. 84.
La Trinità, fossil shells of, iv. 80.
Latta, Dr., on glaciers of Spitzbergen, i. 168.
Lauder, Sir T. D., on floods in Scotland, i. 263.; iii. 55. 219. 250. 253.
——, on parallel roads of Glen Roy, iv. 33.
Laureana, ravines filled near, ii. 277.
Lava, excavated by rivers, i. 268.; iv. 106. 109. 206.
——, effects of decomposition on, ii. 142.
——, flowing of, under water, ii. 145.
——, a bed of oysters between two currents of, iii. 418.
—— and coral alternating, iii. 315.
——, minerals in cavities of, iii. 428.
——, veins of. *See* Dikes.
——, length of time which it requires to cool, iv. 357.
——, solid externally while in motion, iii. 436.
—— and alluvium of different ages in Auvergne, iv. 208.
Lava of Iceland and Central France, ii. 182. 184.
——, comparative volume of ancient and modern, ii. 185.
——, pretended distinction between ancient and modern, ii. 195.
——, mineral composition of, ii. 223. 395.
La Vissière limestone, iv. 205.
Lawrence on causes which enable man to live in all climates, iii. 17.
Lazzaro Moro. *See* Moro.
Leeward Islands, geology of the, iv. 36.
Le Grand d'Aussi, M., on Auvergne, iv. 210.
Lehman, treatise of, 1759, i. 70.
Leibnitz, theory of, i. 45.
Leigh on fossil canoes, iii. 267.
Leith Hill, height of, iv. 243.
Lemings, migrations of, iii. 58.
Lena, R., fossil bones on banks of, i. 145, 146.
Lentini, limestone near, iii. 417.
——, valleys near, their origin, iv. 10.
Leonhard, M., on loess of the Rhine, iv. 45. 51.
——, on volcanic district of Lower Rhine, iv. 126.
——, on granites of different ages, iv. 350.
Lesbos, Antissa joined to by delta, i. 17.
Lewes, human bones in tumulus near, iii. 236.
——, estuary, of the Ouse recently filled up near, iii. 286.
—— Levels, iii. 249.
——, fissures in chalk filled with sand near, iv. 231.
——, ravine called the Coomb near, iv. 254.
——, fault near, iv. 255.
Leybros, limestone of, iv. 73.
Leybucht, bay of, ii. 59.
Lias, strata of the, iv. 299.
—— altered by trap dike and by granite, iv. 373. 377. 391.
Licodia, basalts of, iii. 429.
Liege, caves near, iii. 233.
Light, influence of on plants, i. 155.
Lightning, effect of in Shetland Islands, ii. 14.
Lignite, conversion of wood into, iii. 268.
Lima destroyed by earthquake, ii. 302.
——, valley of, proofs of its successive rise, iv. 32.
Limagne d'Auvergne. *See* Auvergne.

Limburg, loess near town of, iv. 46.
Limestone, origin of, iii. 321.
Lincolnshire, incursions of the sea on coast of, ii. 24.
Lindley, Mr. J., on fossil plants of Melville Island, i. 155.
——, on effect of light on plants, i. 155.
——, on fossil plants of the coal strata, i. 226.
——, on number of plants, iii. 170.
——, on dispersion of cryptogamic plants, iii. 34.
Linnæus on filling up of Gulf of Bothnia, ii. 333.
—— on constancy of species, ii. 407.
—— on real existence of genera, ii. 427.
—— on diffusion of plants, iii. 39. 43.
—— on introduction of species, iii. 98.
—— cited, iii. 110.
Lionnesse, tradition in Cornwall, ii. 49.
Lipari Islands, rocks altered by gases in, iv. 380.
Lippi on destruction of Herculaneum and Pompeii, ii. 149.
Lipsius, i. 20.
Lisbon, earthquakes at, ii. 109. 295.; iii. 272.
Lister the first to propose geological maps, i. 45.
—— on fossil shells, i. 45.
Lloyd, Mr., on relative levels of Atlantic and Pacific, ii. 63.
Lloyd's List, number of wrecked vessels as shown by, iii. 263.
Lochead on gain of land on coast of Guiana, ii. 85.
Loch Lomond, agitation of its waters during Lisbon earthquake, ii. 297.
Lockart, M., on fossils of the Orleanais, iv. 150.
Locke on Whiston's theory, i. 57.
Locusts, devastations by, iii. 116.
——, bank formed in sea by, iii. 117.
Loess of the Rhine, iv. 44.
Loffredo cited, ii. 324, 325.
Loire, tertiary strata of the, iii. 360.; iv. 128.
London basin, tertiary deposits of, i. 209; iii. 357.; iv. 224.
——, on former continuity of Hampshire and, iv. 232.
—— clay, its fossils, composition, thickness, &c., i. 235.; iv. 227.
Long, Mr., on earthquake at New Madrid, ii. 248.
Long Point peninsula cut through by Lake Erie, ii. 64.
Lough Neagh, supposed petrifying power of, i. 325.
Louis de Foix, ii. 76.
Louisiana, Lower, marine strata of, i. 288.
Lowe, Mr., on shells of Madeira, iii. 79.
Lower green-sand described, iv. 235.
Lower Rhine. *See* Rhine.
Lowestoff, current off the coast of, ii. 30.
—— Ness, description of, ii. 30.
——, cliffs, undermined near, ii. 31.
Lowland of Siberia, i. 149. 214.
Lubbock, Mr., i. 180.
Lubeck, ii. 333.
Lucina divaricata, wide geographical range of, iii. 394.; iv. 193.
Luckipour, its inhabitants swept away by the Ganges, i. 359.
——, new islands formed near, i. 358.
Luckput, subsidence near, ii. 238.
Ludlow rocks, fossils of, i. 229.
—— classification of, iv. 283, 284. 306.
Luleo, gain of land at, i. 341.; ii. 334.
Luy, tertiary stata of, iv. 133.
Luzon, active volcanos in, ii. 100.
Lybian sands, caravans overwhelmed by, iii. 212.
Lyme Regis, waste of cliffs at, ii. 47.
Lym-Fiord, a breach made by the sea into, ii. 59.
Lyon, Capt., on imbedding of camels in African sands, iii. 212.

M.

Maars, or lake-craters of the Eifel, iv. 117, 118.
Macculloch, Dr. on gradation from peat to coal, iii. 200.
——, on origin of limestone, iii. 321.
——, on parallel roads of Glen Roy, iv. 33.
——, on Subapennine strata, iv. 66.
——, on granite veins, iv. 345.
——, on junction of granite and limestone in Glen Tilt. iv. 347.
——, on granitic rocks, iv. 349, 350. 355. 377.
——, on trap rocks, iv. 354.
Macedonia subject to earthquakes, ii. 109.
Macgregor, Mr., on earthquakes in Canada, ii. 251.

Mackenzie, Sir G., his supposed section of the pipe of a Geyser, ii. 390.
——, on reindeer in Iceland, iii. 137.
Mackenzie, R., drift-wood of, i. 158.; iii. 243.
——, calcareous formation near its mouth, i. 196.
Maclaren on quantity of useful soil in America, iii. 139.
——, on position of American forests, iii. 188.
Maclure, Mr., on coral and lava in West Indies, iii. 315.; iv. 36.
——, on volcanic district of Olot, iv. 104.
Macmurdo, Captain, on earthquake of Cutch, ii. 237. 242.
Madagascar said to contain active volcanos, ii. 110.
——, extent of coral near, iii. 301.
Madeira, ii. 110.; iv. 37.
Maeler, lake, ii. 338. 345.
Maestricht beds, fossils of, iv. 285.
——, chasm between Eocene and, iv. 286.
——, shells common to the chalk, greensand, and, iv. 285.
Magellan, Straits of, currents in, ii. 6.
Magnesia, deposited by springs, i. 311.
Magnesian limestone and travertin compared, i. 313.
Magnetism, terrestrial, phenomena of, ii. 367.
Magnan, R., section in valley of, iv. 79.
Mahomet, his cosmogony, i. 31.
Majoli, opinions of, i. 37.
Malabar, coral near, iii. 302.
Malaga, tertiary strata of, iv. 84.
Malcolm, Sir J., on buried cities in Central India, iii. 216.
Maldivas, chain of coral islands, iii. 301.
Mallet, Captain, on petroleum of Trinidad, i. 330.
Malpais, theories to account for convexity of the plain of, ii. 187. 211.
Malte-Brun cited, i. 164. 177.; ii. 59.; iii. 63. 74. 92. 97. 213. 246. 254.
Mammalia, different regions of indigenous, iii. 48.
——, fossil, importance of remains of, iii. 380.; iv. 52.
——, of successive tertiary periods, iii. 401.
——, remains of, rare in the older rocks, iv. 317.
Mammoth, climate, &c., probably required by the, i. 141.
Mammoth, bones of, in Yorkshire, i. 142.
——, in tufa near Rome, iv. 43.
Man, unfavourable position of, for observing changes now in progress, i. 118.
——, recent origin of, i. 239.; iii. 138. 278.
——, remarks on the superiority of, i. 242.
——, causes which enable him to live in all climates, iii. 17.
——, his agency in dispersion of plants and animals, iii. 42. 95.
——, diffusion of, iii 89.
——, probable birth-place of, iii. 89.
——, changes caused by, i. 247.; iii. 127. 187.
——, durability of the bones of, i. 241.; iii. 265.
——, remains of, in osseous breccias of the Morea, iii. 227.
——, his remains and works fossilized, iii. 254. 258.
Manetho, i. 112.
Manfredi on sediment in river water, i. 362.
Mansfeld, fossils of, iv. 301.
Mantell, Mr., on bones from Saxon tumulus, iii. 236.
——, on Lewes Levels, iii. 249. 286.
——, on fossil shells of the crag, iv. 85.
——, on tertiary outliers on chalk, iv. 231.
——, on the Weald Valley, iv. 235. 237. 248. 293.
——, on "elephant bed" at Brighton, iv. 274.
——, on fossils of the chalk, iv. 289.
——, on fossil forest of I. of Portland, iv. 295.
——, on a fault in the cliff-hills near Lewes, iv. 255.
Manwantaras, oriental cycle of ages, i. 7.
Maracaybo, lake, ii. 246.
Marble deposited from springs, i. 322.
Marculot, limestone of, iv. 165.
Marienforst, blocks of quartz, with casts of shells near, iv. 125.
Marine alluviums, iii. 220.
Marine testacea, range of, iii. 383.
Marine and freshwater strata, alternations of, iii. 287.
Marine deposits, imbedding of freshwater species in, iii. 288.
Marine deposits, contain in general a great variety of species, iii. 288.

Marine plants and animals, imbedding of remains of, iii. 283. 290.
Marine vegetation, iii. 29. 36.
Maritime Alps, conglomerates forming at base of, i. 371.
——, tertiary strata at base of, iv. 75.
Marl-lakes of Scotland, animals and plants fossilized in, iii. 256. 282.
Marsilli, on arrangement of shells in Adriatic, i. 63. 66.
——, on deposits of coast of Languedoc, i. 345.
Marstrand, island of, ii. 341.
Marsupial animals, distribution of, iii. 50.
——, in breccias in Australian caves, iv. 56.
Martigny destruction of, by floods, i. 293.
Martin, Mr., on Valley of the Weald, iv. 291.
——, on transverse valleys of North and South Downs, iv. 251.
——, on thickness of strata removed from summit of Forest ridge, iv. 271.
Martinique, subsidence in, ii. 304.
Martin Meer, fossil canoes in, iii. 267.
Martius, on drifting of animals by the Amazon, iii. 63.
——, on Brazil, iii. 129.
Maryland, whirlwind in, iii. 32.
Mascalucia, subsidence near, iii. 448.
Mathers, village of, swept away by sea, ii. 19.
Matilda coral island, iii. 312.
Mattani on fossils of Volterra, i. 59.
Mattioli on organic remains, i. 36.
Mayence, tertiary strata of, iv. 144.
Mayer, M., on mineral veins, iv. 382.
Mayne, Valley of the, iv. 46.
Medesano, lignite at, iv. 68.
Mediterranean said to have burst through the columns of Hercules, i. 24.
——, microscopic testacea of, i. 77.
——, deposition of salt in the, ii. 67.
——, its former union with the Red Sea, ii. 83.
——, new island in, ii. 199.
——, organic remains of, iii. 349.; iv. 131.
——, shells drifted into, iii. 382.
——, its temperature, depth, level, &c., i. 78. 349.; ii. 67. 69. 317.
Medway, transverse valley of the, iv. 251.
Meerfelder Maar described, iv. 119.
Megalosaurus Bucklandi, iv. 296.
Melania inquinata, iii. 394.
Melilli, circular valley near, iv. 7.
——, inland cliffs near, iv. 8.
Melville Island, fossils of, i. 155.
——, migrations of animals into, iii. 62.
Mendip hills, caves of, iii. 234.
Menu's Institutes, i. 6. 8.
Mercati on organic remains, i. 36.
Merdogne, marls intersected by a dike near, iv. 199.
Mersey, vessel in bed of, iii. 267.
Mese, formerly an island, i. 343.
Messenia, conglomerate of, iv. 288.
Messina, ebb and flow in Straits of, ii. 2.
——, earthquake at, ii. 261. 279.
Mesua Collis described by Pomponius Mela, i. 343.
Metallic nucleus, theory of an unoxidated, ii. 370.
Metallic substances changed by submersion, iii. 269.
Metamorphic, the term proposed and defined, iv. 386.
—— rocks of the Alps, iv. 376.
——, sometimes pass into sedimentary, iv. 388.
——, in what manner their age should be determined, iv. 391.
——, why those visible to us are for the most part ancient, iv. 392.
Methone, eruption in, ii. 108.
Metshuka, hill of, ii. 294.
Meuse, valley of the, i. 260.
Mexico, tides in Gulf of, i. 360.
——, volcanic chain extending through, ii. 97.
Meyen, Mr., on earthquake in Chili, 1822, ii. 233.
Mhysir, buried city, iii. 217.
Micaceous schist, whence derived, iv. 382.
Michell on cause and phenomena of earthquakes, 1760, i. 72.
——, originality of his views, i. 72.
—— on the geology of Yorkshire, i. 72.
—— on earthquake at Lisbon, ii. 109. 298.
—— on retreat of the sea during earthquakes, ii. 299.
—— on cause of the wave-like motion of earthquakes, ii. 379.
Microscopic fossil shells of Sienna, iv. 74.

Microscopic fossil shells of the Crag, iv. 87. 101.
—— of Paris basin, *see* plate, iv. 189.
Migrations of animals, iii. 57.
—— of cetacea, iii. 65.
—— of birds, iii. 66.
—— of fish, iii. 73.
—— of insects, iii. 83.
Migratory powers indispensable to animals, iii. 142.
Mileto, subsidence near, ii. 275.
Milford Haven, rise of tides at, ii. 3.
Miliolite limestone, iv. 189.
Millennium, i. 34. 54.
Milo island, solfatara in, ii. 108.
Mindinao in eruption, 1784, ii. 100.
Mineral waters, their connection with volcanic phenomena, i. 304.
——, ingredients most common in, i. 307.
Mines, heat in, augments with the depth, ii. 356.
Miocene period, term whence derived, iii. 392.
——, proportion of living species in fossil shells of the, iii. 392.
——, mammiferous remains of, iii. 401.
——, marine formations of, iv. 127.
——, freshwater formations of, iv. 150.
——, volcanic rocks of, iv. 153.
——, alluviums of, iv. 147.
Mirambeau, red clay and sand of, iv. 135.
Mismer, crag strata near, iv. 93.
Mississippi, its course, depth, velocity, &c., i. 277. 281.
——, drift-wood of the, i. 280. 361.; iii. 63. 245
——, earthquakes in valley of, i. 287.; ii. 98. 246.
——, delta of, i. 360. 372.
Missouri, its junction with the Mississippi, i. 278.
Misterbianco, valleys of, iii. 423.
Mitchell, Dr., on waste of cliffs, ii. 35. 37.
Mitchell, Major, on Australian caves, iv. 56.
Mitscherlich, M., on minerals found in Somma, iv. 19.
Modern causes, remarks on the term, iv. 277.
Molasse, its place in series of tertiary formations not yet known, iv. 140.
Mole, R., transverse valley of, iv. 251.
Molino delle Caldane, travertin, i. 309.
Moluccas, eruption in the, ii. 306.
Molluscous animals, superior longevity of the species of, iii. 383.
Mompiliere, articles preserved under lava in, ii. 172.
Monfalcone, baths of, i. 348.
Mons, secondary strata near, iv. 284.
Mont Blanc, glaciers of, i. 265.
—— Dor, volcano of, iv. 202, 203.
—— Ferrat, tertiary strata of, iii. 360.
—— Mezen, age of the, iv. 201.
—— Perrier, alluviums and breccias of, iv. 147.
Monte Barbaro, description of, ii. 127.
—— Bolca, fossil fish of, i. 77.
—— Calvo, section from, to the sea, iv. 80.
—— Cerio, shells in gypsum of, iv. 68.
—— Grifone, caves in, iv. 53.
—— Mario, strata of, iv. 44. 70.
—— Minardo, its height, &c., ii. 166.
—— Nucilla, ii. 167.
—— Nuovo, formation of, ii. 124.; iv. 3. 25. 29.
——, coast of Bay of Baiæ elevated during eruption of, i. 50.; ii. 124. 325.
—— Peluso, ii. 167.
—— Rotaro, ii. 115.
—— Somma, structure of, ii. 138. 217.
—— Vico, siliceous incrustations of, i. 325.
Monticelli and Covelli on Vesuvian minerals, ii. 144.
Monti Rossi described, ii. 169.
Montlosier on Auvergne, i. 86.; iv. 205. 210.
Montmartre, gypsum of, iv. 185.
——, fossils of, iv. 192.
Montpellier, cannon in crystalline rock at, i. 345.
——, tertiary strata of, iv. 138.
Montrose, no delta in bay of, ii. 19.
Montsacopa, volcanic cone of, iv. 106.
Moon, mountains in the, ii. 222.
Morayshire, effect of floods in, iii. 219. 253.
Morea, cities submerged in the, ii. 108.
——, Céramique of, iii. 222.
——, osseous breccias now forming in the, iii. 225.
——, closed basins and engulphed rivers in the, iii. 226.
——, human remains imbedded in the, iii. 227.
——, sea-cliffs at various elevations in the, iv. 34.
——, tertiary strata of, iv. 84.

Morea, cretaceous rocks of the, iv. 288.
Morren, M., on peat of Flanders, iii. 209.
Moro, Lazzaro, on earthquakes, 1740, i. 59.
——, on new island in Mediterranean, i. 60.
——, on nature of organic remains, i. 60.
——, on faults and dislocations, i. 60.
——, on secondary strata, i. 61.
——, on origin of stratified rocks, i. 66.
——, on primary rocks, i. 90.
Morocco, earthquakes at, ii. 109. 297.
Moropano, shells in tuff near, iv. 27.
Mosasaurus of Maestricht found in the English chalk, iv. 289.
Moselle, R., sinuosities of, i. 259.
Mosenberg, extinct volcano, iv. 119.
Mountain-chains, on the elevation of, i. 115.
——, on relative antiquity of, iv. 327.
——, difficulty of determining the relative ages of, iv. 341.
Mountain limestone formation, i. 196. iv. 301.
Mud eruption in Quito, 1797, ii. 250.
Mules sometimes prolific, iii. 3.
Mundane egg of Egyptian cosmogony, i. 15.
Mundesley, chalk in crag near, iv. 99.
Munkholm, Island of, ii. 345.
Munster, Count, on Maestricht fossils, iv. 285.
——, on fossils of Solenhofen, iv. 299.
——, on Gosau fossils, iv. 290.
Murat, deposits near, iv. 205.
Murchison, Mr., on the Hartz mountains, i. 83.
——, on tertiary deposits of the Alps, i. 205.
——, on the coal strata, i. 197.; iv. 303.
——, on transition fossils, i. 229.
——, on schists of Caithness, i. 230.
——, on tertiary strata of Lancashire, i. 211.
—— of Nice, iv. 39.
—— of maritime Alps, iv. 78, 79.
—— of the Superga, iv. 139.
—— of Styria, iv. 141. 143. 155.
—— of Cadibona, iv. 153.
—— of Central France, iv. 157. 175. 198. 205.
—— of Aix, iv. 223.
——, his section of crag resting on chalk, iv. 90,
——, on excavation of valleys, iv. 208.
Murchison, Mr., on upper green-sand, iv. 261.
——, his new arrangement of the transition strata, iv. 306.
Murcia, earthquake of 1829, ii. 229.
Murphy, Lieut. H., on height of North Downs, iv. 237.
Murrayshire, town in, swept away by sea, ii. 19.
Musara, buried cones near, iii. 438.
——, flowing of lava round, iii. 443.
——, traversed by dikes, iii. 443.
Muschelkalk, iv. 300.
Mydaus meliceps, iii. 60.

N.

Nadder, valley of the, iv. 263.
Nakel, fossil ship found at, iii. 267.
Nantucket, banks of, ii. 5.
Naples, history and map of volcanic district round, ii. 113.; iv. 16.
——, recent tertiary strata in district round, iii. 362.
——, recent shells in tuffs near, iv. 26.
Narwal stranded near Boston, iii. 289.
——, fossil, near Lewes, iii. 286.
Nassau, loess found in, iv. 46.
Nature, as defined by Lamarck, ii. 419.
Necker, M. L. A., on Somma, ii. 217.; iv. 20. 23.
Needles of Isle of Wight, ii. 44.
——, fall of one of them, iv. 100.
Neill on whales stranded, iii. 289.
—— on mineral veins, iv. 382.
Nelson, Lieut., on coral reefs, iii. 301.
Neptune, temple of, under water, ii. 321.
Neptunists and Vulcanists, rival factions of, i. 87. 97.
Nerbuddah R., iii. 216.
Nesti, M., on fossils of Upper Val d'Arno, iv. 152.
Netherlands, tertiary formations of the, iv. 223.
Newcastle coal-field, i. 197.
Newer Pliocene period. *See* Pliocene period, *newer*.
Newfoundland, cattle mired in bogs of, iii. 207.
Newhaven, its cliffs undermined, ii. 43.
——, tertiary strata on chalk near, iv. 235.
New Holland, plants of, i. 191.; iii. 26.
——, animals of, iii. 50.
——, coral reefs of, iii. 301.
New Kameni, formation of, ii. 209.
New Madrid, earthquakes at, ii. 246.

New York, excessive climate of, i. 165.
New Zealand, animals in, i. 199.
Niagara, excavation caused by the cataract of, i. 130. 273.
——, falls of, i. 271.
——, probable time which they will require to reach Lake Erie, i. 274.
Nicaragua, volcanos in, ii. 97.
Nice, depth of Mediterranean near, i. 349. 371.; ii. 70.
——, tertiary strata of, i. 349.; iv. 77. 79.
Nicolosi destroyed by earthquake, ii. 169.
Niebuhr, cited, i. 108.
Niger, delta of, its size, iv. 316.
Nile, delta of the, i. 349.; iii. 370.
——, its ancient mouths, i. 350.
——, analysis of mud of the, i. 351.
——, cities buried under blown sand near the, iii. 210.
——, men swept away by flood of, iii. 258.
Nilsson, M., on lignite of the chalk period, iv. 289.
—— on migrations of eels, iii. 75.
Nipon, volcanos numerous in, ii. 100.
Nitrogen in springs, iii. 180.
Noeggerath, M., on volcanic district of the Rhine, iv. 115. 126.
Norfolk, waste of cliffs of, ii. 24.; iv. 249.
——, gain of land on coast of, ii. 27.
——, crag strata of, iv. 85.
Norte, R., transportation of sediment by the, ii. 85.
North Cape, drift-wood on, iii. 246.
North Downs, chalk ridge called the, iv. 236.
——, section across valley of Weald from south to, iv. 237.
——, highest point of, iv. 237.
——, on former continuity of chalk of the, with that of the South Downs, iv. 257.
Northmavine, rocks drifted by sea at, ii. 13.
Northstrand destroyed by sea, ii. 59.
Northumberland, land destroyed by sea in, ii. 21.
Noto, Val di, formations of the, iii. 405.
Notre Dame des Ports, i. 343.
Norway free from earthquakes, ii. 348.
——, rise of land in, i. 211.; ii. 342. 345.
Norwich once situated on an arm of the sea, ii. 27.
Nugent, Dr., on Pitch Lake of Trinidad, i. 330.
Novera, hill of, in Sicily, iii. 414.
Nymphs, temple of, under water, ii. 321.
Nyöe, a new island formed in 1783, ii. 180. 198.

O.

Obsequens on eruption in Ischia, ii. 123.
Oby, R., fossils on shores of, i. 145.
Ocean, permanency of its level, ii. 329.
Oceanic deltas, i. 353.
Odoardi on tertiary strata of Italy, i. 73.; iii. 358.
Oersted, discoveries of, ii. 367.
Ogygian deluge, ii. 104. 121.
Ohio, junction of with Mississippi, i. 278.
Olafsen on drift-wood, iii. 247.
Older Pliocene period. *See* Pliocene period, *older*.
Old red sandstone, fish found in, i. 230.
Olivet, volcanic cone of, iv. 106.
Olivi on fossil remains, i. 37.
—— on sediment in Adriatic, i. 348.
Olot, volcanic district of (*see* Pl. xi.), iv. 103.
——, destroyed by earthquake, iv. 112.
Omalius d'Halloy, on former connection of Auvergne and Paris basin, iv. 178.
Omar, an Arabian writer, i. 29.
Oojain. *See* Oujein.
Oolite, or Jura limestone formation, iv. 298.
——, converted into hypogene rock in the Alps, iv. 376.
——, fossils of the, i. 232.; iv. 299.
Oolitic structure, in Auvergne, iv. 165.
—— in Hungary, iv. 143.
——, recent, in Lancerote, ii. 197.
Opossum, fossil, at Stonesfield, i. 232.
Oppido, changes caused by earthquake near, ii. 258. 267.
Orcia, river, i. 311.
Orang-outang, Lamarck on its conversion into the human species, ii. 421.
Organic life, effect of changes in land and sea on, i. 177.
Organic remains, controversy as to real nature of, i. 33.; iii. 328.
——, imbedding of. *See* Fossilization.
——, importance of the study of, i. 105.
——, abrupt transition from those of the secondary to those of the tertiary rocks, i. 206.
——, contemporaneous origin of rocks proved by, iii. 347.
——, comparative value of different classes of, iii. 379.

Organic remains. *See* also Fossils.
Orinoco, R., subsidence in, ii. 294.
Orkney Islands, promontory cut off by sea in, ii. 18.
Orleanais, fossils of the, iv. 150.
Orpheus, cited, i. 12.
Orthès, tertiary strata of, iv. 133.
Orust, island of, ii. 343. 345.
Orwell river, ii. 34.
Osnabruch, tertiary strata of, iv. 146.
Osseous breccias, formation of, iii. 231.
——, in caves, iv. 51. 56.
——, now forming in the Morea, iii. 225.
Otaheite, volcanos in, iii. 310.
——, coral at great height in, iii. 318.
Otranto, tertiary strata of, i. 138.; iii. 362.
Oujein, buried city of, ii. 242.; iii. 215.
Ouse, R., transverse valley of, iv. 251.
——, has filled up an arm of the sea, iii. 286.; iv. 253.
Outlying patches of tertiary strata on chalk hills, iv. 231.
Ovid, cited, i. 15.
Owen, Mr., on bones of turtles, iii. 291.
Owhyhee, iii. 310.
Owthorne, encroachment of sea at, ii. 34.
Oxus, earthquake in valley of the, ii. 102.
Oxygen, its action on rocks, i. 257.
Oysters, &c., thrown ashore alive by storm, iii. 293.
——, migrations of, iii. 81.

P.

Pachydermata, abundant in Eocene period, iii. 401.
Pacific Ocean, depth of, i. 180.
——, its height above the Atlantic, ii. 62.
——, animals in islands of, iii. 53.
——, subsidence greater than elevation in, iii. 316.
——, earthquakes in, iii. 318.
——, coral and volcanic islands of, ii. 101.; iii. 306. 309. 318.
——, lines of ancient sea cliffs on shores of, iv. 32.
Pæstum, formation of limestone near, i. 315.
Pakefield, waste of cliffs at, ii. 32.
Palæotherium in freshwater strata of Isle of Wight, iv. 229. 276.
Palagonia, dikes at, iii. 413.
——, section to Paterno from, iii. 422.
Palermo, caves containing osseous breccias near, iv. 53.
Palestine shaken by earthquakes, ii. 106.
Palissy on organic remains, i. 38.
Pallas on mountains of Siberia, i. 78.
—— on Caspian Sea, i. 79.; ii. 104.
—— on fossil bones of Siberia, i. 79. 145, 146.
—— on calcareous springs, i. 321.
—— cited, ii. 64. 105. 363.; iii. 96.
Palma, description of Isle of, ii. 213.
Panama, tides in Bay of, ii. 63.
Panella, in Ischia, iv. 28.
Papandayang, eruption of, ii. 293.
—— its cone truncated, ii. 293.; iii. 447.
Papa Stour, waste of rocks of, ii. 17.
Papyrus rolls in Herculaneum, ii. 156.
Paradise, Burnet on seat of, i. 55.
Parallel roads of Coquimbo, iv. 32.
—— of Glen Roy, iv. 33.
Paris basin, formations of the, i. 209.; iii. 354.; iv. 177.
——, fossils of the, i. 235.; iii. 355. 394.; iv. 189. 190.
——, all tertiary formations at first referred to age of, iii. 356.
——, analogy of deposits of Central France to those of the, iv. 177.
——, comparison between English Eocene deposits and those of, iv. 230.
Parkinson, Mr., on the crag, iii. 358.; iv. 64.
Parma, tertiary strata near, i. 138. 275. 349.; iii. 386.; iv. 67.
Paroxysmal elevations, theory of, iv. 29.
Parrot on Caspian Sea, ii. 103.; iii. 148.
——, retraction of his opinion on level of Caspian, iv. 215.
Parry, Captain, highest northern latitude reached by, i. 171.
—— on migration of Polar bear, iii. 61.
—— on animals of Melville Island, iii. 62.
Partsch, M., on tertiary strata of Vienna, iv. 141.
Passo Manzanelli, waterfalls in lava at, i. 270.
Pasto, volcanos in, ii. 97.
Paternò, section from, to Palagonia, iii. 422.
——, valleys of, iii. 423.
——, age of basalts of, iii. 429.
Patrizio's dialogues, i. 58.
Pauliac, limestone of, iv. 134.
Paviland cave, iii. 234.

Peat, on its growth, and preservation of fossils in it, iii. 182. 199. 208.
—— bogs, bursting of, iii. 208.
——, submarine, iii. 209. 288.
Pedamentina, description of the, ii. 139.
Pelagian formations, their internal arrangement, ii. 88.
Pembrokeshire, tradition of loss of land in, ii. 50.
Pennant on encroachments of sea on Yorkshire coast, ii. 22, 23.
—— on distribution and migration of animals, i. 144.; iii. 52. 58.
Pentalica, limestone of, iii. 406, 407.
Pentland, Mr., on fossils from Australian caves, iv. 57.
——, on fossils of Upper Val d'Arno, iv. 151.
Pentland Firth, currents in the, ii. 6.
Penzance, loss of land near, ii. 49.
Peperino, dikes in, iii. 412.
——, how formed, iii. 415.
——, dikes of, how formed, iii. 414.
Péron on distribution of animals, iii. 73. 82.
—— on Island of Timor, iv. 40.
Perpignan, iv. 112.
Persian Gulf, coral in, iii. 301.
Persian Magi on the deluge, i. 31.
Peru, volcano in, ii. 94.
——, earthquakes in, ii. 94. 302.
——, proofs of successive elevation of coast of, iv. 32.
Peterhead, whale stranded near, iii. 289.
Petroleum springs, i. 329.
Pewsey, Vale of, iv. 263.
Pharos joined to Egypt by delta of Nile, i. 17. 350.
Phillips, Mr. J., on waste of Yorkshire coast, ii. 22.
——, on tertiary strata in Yorkshire, iv. 88.
Phillips, Mr. R., on slow deposition of some kinds of sediment, ii. 87.
Phillips, Mr. W., his analysis of chalk flints, iv. 173.
Philosopher's tower on Etna, iv. 30.
Phlegræan fields, volcanos of, ii. 127.; iv. 25.
Physical Geography. See Geography.
Piana, conglomerate of, iv. 139.
Piazza, tertiary strata at, iii. 419.
Pichinca volcano, ii. 95.
Piedmont, tertiary strata of, iii. 360.; iv. 138.
Pietra Mala, inflammable gas of, i. 18.
Pignataro on earthquake of Calabria, ii. 255.
Pigs, instincts of, ii. 457.
—— swim to great distances, iii. 55.
——, fossil, iii. 205.
Pindar cited, ii. 168.
Pingel, M., on subsidence of Greenland, ii. 346.
Pitch Lake of Trinidad, i. 330.
Pitchstone, formed by dikes of Somma, iv. 23.
Piteo, gain of land at, i. 341.; ii. 334.
Pius VII., edict against Galileo and Copernican system, repealed by, i. 99.
Piz, fall of mountain of, iii. 222.
Plants, varieties in, produced by horticulture, ii. 443.
——, extent of variation in, ii. 445.
——, their geographical distribution, iii. 24.
——, in islands, iii. 27. 36. 109.
——, dispersion of, iii. 31. 34. 38, 39. 42.
——, stations of, iii. 25. 107.
——, equilibrium among, kept up by insects, iii. 110.
——, number of terrestrial, iii. 170.
——, imbedding of, in subaqueous deposits, iii. 241. 281. 288.
——, on number which are now becoming fossil, iii. 248.
——, their fossilization partial, iii. 372.
——, fossil, importance of, in geology, iii. 379. 381.
——, fossil, of the coal strata, i. 154. 197. 226.
Plas Newydd, changes caused by a dike near, iv. 371.
Plastic clay and sand of the London basin, i. 235.; iv. 225.
—— of the Paris basin, iv. 181.
Plastic force, fossil shells ascribed to, i. 33.
Plato on Egyptian cosmogony, i. 12.
Playfair on Huttonian Theory, i. 93. 100.
—— on instability of the earth's surface, i. 295.
—— on gradual rise of Sweden, ii. 335.
—— on formation of vegetable soil, iii. 178.
—— cited, ii. 363.
Pleurs, town of, and its inhabitants buried by a landslip, iii. 223.
Pliny, the Elder, i. 26.
——, on delta of Rhone, i. 342.

Pliny the Elder, on islands at the mouth of the Texel, ii. 57.
——, killed by eruption of Vesuvius, A. D. 79, ii. 119.
Pliny the Younger, on eruption of Vesuvius, A. D. 79, ii. 119.
—— does not mention the overwhelming of Herculaneum and Pompeii, ii. 119.
Pliocene period, *newer*, derivation of the term, iii. 390.
——, proportion of living species in fossil shells of, iii. 391. 395.
——, marine formations of, iii. 404.
——, volcanic rocks of, iv. 17.
——, subterranean rocks of fusion, formed during, iv. 4.
——, freshwater formations of, iv. 42.
——, osseous breccias and cave deposits of, iv. 51.
——, alluviums of, iv. 57.
Pliocene period, *older*, proportion of living species in fossil shells of, iii. 391. 395.
——, mammiferous remains of, iii. 401.
——, formations referrible to the, iv. 63.
——, volcanic rocks of, iv. 102.
Pliocene strata of Sicily, origin of, iv. 1.
——, changes of surface during and since their emergence, iv. 6.
——, *newer*, chiefly visible in countries of earthquakes, iv. 31. 40.
Plomb du Cantal, successively accumulated, iv. 175.
——, volcanic rocks of, iv. 201. 204.
——, limestone covered by volcanic rocks on, iv. 205.
——, not an elevation crater, ii. 221.
Plot on organic remains, i. 44.
Pluche, theory of, 1732, i. 57.
Plutarch, i. 11.
Plutonic rocks, iv. 344.
——, distinction between volcanic and, iv. 352.
——, their relative age, iv. 358. 390.
——, changes produced by, iv. 374.
——, why those now visible are for the most part very ancient, iv. 392.
Po, R., frequently shifts its course, i. 275.
——, embankment of the, i. 276.
——, delta of the, i. 346. 370.; iii. 192.
Podolia, tertiary formations of, iv. 144.
Polistena, changes caused by earthquakes near, ii. 262. 270. 275.
Polyps, *see* Zoophytes.
Pomerania, fossil ships in, iii. 267.
Pompeii, how destroyed, ii. 147. 151.
——, section of the mass enveloping, ii. 148.
——, depth to which the ashes of eruption of 1822 covered, ii. 148.
——, objects preserved in, ii. 155.
Pomponius Mela, cited, i. 343.; ii. 56.
Pondres, cave at, iii. 236.
Pontanus on eruption in Ischia, ii. 123.
Pont du Chateau, tuff and limestone at, iv. 198.
Ponte Leucano, travertin at, i. 317.
Pont Gibaud, gneiss rocks decomposed by carbonic acid at, i. 328.
——, calcareous springs near, i. 308.
Poole Bay cut into by sea, ii. 46.
Popayan, volcanos in, ii. 97.
——, shaken by earthquake, ii. 231.
Port-au-Prince destroyed by earthquake, ii. 299.
Portland, fossil ammonites of, i. 48.
——, its peninsula continually wastes, ii. 46.
——, fossil forest in, iv. 294.
Port Royal, subsidence of, ii. 307.; iii. 146. 272. 278.
Portugal, earthquakes in, ii. 109. 295.
Port Vallais, ancient town in delta of Rhone, i. 334.
Po Vecchio, i. 276.
Pratt, Mr., on fossils of Isle of Wight, i. 236.; iv. 229.
——, on cave of San Ciro, iv. 53.
Precession of the equinoxes, i. 174.
Prevost, M. C., on gypseous springs of Baden, i. 323.
——, on new island in Mediterranean ii. 201.
——, on fossil mammalia of Stonesfield, i. 232.
——, on elevation craters, ii. 223.
——, on geological causes, iii. 198.
——, on drifting of plants, iii. 245.
——, on filling up of caves with osseous breccias, iii. 232.
——, on tertiary strata of Vienna, iii. 361.; iv. 141.
——, on tertiary strata of Paris basin, iv. 180. 184. 186. 191.
Prevost, M. P., on radiation of heat, i. 163.
Prevost, Mr. J. L., on number of wrecked vessels, iii. 263.
Pressure, effects of, on consolidation of strata, iv. 324.
Prichard, Dr., on Egyptian cosmogony, i. 11. 244.

Prichard, Dr., on recent origin of man, i. 241.
——, on distinct origin of dog and wolf, ii. 433.
——, on hybrid races, iii. 4.
——, on facial angle, iii. 16.
——, on distribution of animals, iii. 49. 52.
Primary, on the rocks usually termed, iii. 335.; iv. 343.
——, their relation to volcanic and sedimentary formations, iv. 343.
——. divisible into two groups, iv. 344.
——, on the stratified rocks called, iii. 339.; iv. 360.
——, the term why faulty, iv. 385.
——, strata, how far entitled to the appellation, iv. 390.
Primitive, term now abandoned, iii. 340.
Primosole, limestone at, iii. 420.
Prinsep, Mr., on sediment of Ganges, i. 364.
Priory of Crail, swept away by sea, ii. 21.
Procida, island of, remarks of ancient writers on, ii. 114.
—— would resemble Ischia if raised, iv. 28.
Progressive development of organic life, theory of, i. 222.; ii. 407.
Promontories, their effect in protecting low shores, ii. 19.
Psalmodi, formerly an island, i. 343.
Puglia, fossil elephant found at, i. 36.
Pulo Nias, fossil shells of, iv. 37.
Pulvermaar, described, iv. 118.
Punto del Nasone, dikes at, iv. 21.
Punto di Guimento, veins of lava at, iii. 442.
Puracé, extinct volcano of, iv. 191.
Purbeck, its peninsula wasting, ii. 46.
Pursh on plants of United States, iii. 26.
Pusanibio. R., sulphuric acid, &c. in waters of, iv. 191.
Puy Arzet, chalk with beds of tuff in, iv. 133.
Puy de Come, ravine in lava of, iv. 206.
Puy de Jussat, quartzose grits of, iv. 161.
Puy de Marmont, tuff and marl in, iv. 198.
Puy de Pariou, iv. 212.
Puy Griou, iv. 204.
Puy Rouge, ravine in lava of, iv. 207.
Puy de Tartaret, iv. 206.
Puy en Velay, fossils in alluvium under lava near, iv. 149.
——, freshwater formation of, iv. 170.
Puzzuoli, Temple of Serapis near, ii. 312.
——, inland cliffs near, ii. 313. 315.; iv. 9.
——, date of re-elevation of coast of, ii. 323.
——, encroachment of sea near, ii. 327.
——, no great wave caused by rise of coast near, iv. 29.
Pyrenees, their relative age, height, &c., i. 206.; iv. 333. 375.
——, tertiary formations of, iv. 83. 133. 334.
——, lamination of clay-state in, iv. 368.
——, chalk of the, iv. 287, 288.
Pythagoras, system of, i. 15.
——, on Etna, ii. 91.

Q.

Quadrumanous animals not found fossil, i. 237.
Quadrupeds, domestic, multiply rapidly in America, iii. 134.
——, imbedding of terrestrial, iii. 251.
Quaggas, migrations of, iii. 59.
Quartz, whence derived, iv. 382.
Quebec, climate of, i. 165.
——, earthquakes in, ii. 251.
Quero destroyed by earthquake, ii. 250.
Quilotoa, Lake, cattle killed by vapours from, ii. 250.
Quintero elevated by earthquake of 1822, ii. 231.
Quirini, theory of, i. 43.
Quito, earthquakes in, ii. 250. 306.
Quorra, or Niger, delta of the, iv. 316.
Quoy, M., on coral zoophytes, iii. 303.

R.

Rabenstein cave, iii. 232.
Race of Alderney, its velocity, ii. 6.
Radicofani, marls capped by basalt at, iv. 68.
——, age of volcanic rocks of, iv. 102.
Radusa, fossil fish of, iii. 411.
Raffles, Sir S., cited, ii. 243. 464.
Rafts, drift-timber in Mississippi, &c., i. 282.
Rain, action of, iii. 186.

Rain, diminished by felling of forests, iii. 187.
Ramazzini on Burnet's theory, i. 58.
Ramond, M., on Auvergne, iv. 210.
Rancié, altered lias at, iv. 375.
Raspe on islands shifting their position (note), i. 18.
——, his theory, 1763, i. 74.
——, on earthquakes, i. 74.
——, on new islands, i. 75.
——, on basalt, i. 84.
——, on elevation of coast of Chili, ii. 302.
Rats, migrations of, iii. 58.
—— introduced by man into America, iii. 95. 136.
Ravenna, formerly a sea-port, i. 347.
Ray, his physico-theology, i. 51. 53.
——, on earthquakes, i. 52.
——, on encroachments of sea, i. 52.; ii. 32.
——, on Woodward's theory, i. 54.
——, cited, iii. 71.
Reaumur on insects, iii. 41.
Recent formations, term explained, iii. 385.
——, form a common point of departure in all countries iii. 400.
Recent and tertiary formations, synoptical table of, iii. 403.
Reculver cliff, encroachment of sea on, ii. 36.
Recupero on flowing of lava, ii. 172.
Red marl, supposed universality of, iv. 322.
——, and sandstone of Auvergne, iv. 161. 323.
Red River, formation of new lakes by, i. 286.; iv. 50.
——, drift-wood in, i. 282.
Red River and Mississippi, their junction recent, i. 370.
Red Sea, gain of land in, ii. 80.
——, level of, ii. 62.
——, coral reefs of, iii. 298. 304. 310. 314.
——, on former union of Mediterranean and, ii. 83.
—— and Mediterranean, distinct species in, iii. 350.; iv. 131.
——, tertiary strata on borders of, iv. 39.
Refrigeration, Leibnitz's theory of, i. 45.
——, causes which might produce the extreme of, i. 181.
Rein-deer, geographical range of, iii. 57.
——, migrations of, iii. 62.
——, imported into Iceland, iii. 137.
Remains, organic; *see* Fossils and Fossilization.
Rennell, Major, on delta of Ganges, i. 354. 358.
——, on icebergs, i. 169.
——, on delta of Nile, i. 349.
——, on sediment in waters of Ganges, i. 363.
——, on currents, i. 166.; ii. 4. 6, 7.
——, on the tide-wave called the Bore, ii. 61.
——, on level of Red Sea, ii. 62.
Rennes, tertiary strata near, iv. 222.
Rennie, Rev. Dr., on peat, and fossils in peat, iii. 199, 200. 204, 205. 210.
Reptiles, their geographical distribution, iii. 70.
——, their powers of diffusion, iii. 71.
——, in Ireland, iii. 71.
——, imbedding of in subaqueous deposits, iii. 249. 254. 290.
Resina, overflowed by lava, ii. 129.
Rhine, R., description of its course, ii. 53.
——, its delta, ii. 53.
——, Lower, volcanos of the, iv. 114.
——, origin of trass of, iv. 121.
Rhinoceros, fossil, in Siberia, i. 147.
Rhone, delta of, in Mediterranean, i. 341.
——, delta of, in Lake of Geneva, i. 333. 368.; iii. 368.
——, debris deposited at its confluence with the Arve, i. 374.
——, shells, drifted by the, iii. 382.
——, a cannon imbedded in calcareous rock in its delta, iii. 269.
Riccioli, Signor, on travertin, iv. 43.
Richardson, Dr., on formation of icebergs, i. 152.
——, on a calcareous formation near the Mackenzie River, i. 196.
——, on drift-timber in the Mackenzie and Slave Lake, iii. 243. 245.
Richardson, Mr. W., on Herne Bay, ii. 36.
Riobamba destroyed by earthquake, ii. 250.
Rimao, valley of, ancient sea-cliffs in, iv. 32.
Ripple marks, how formed, iv. 94.
Risso, M., on fossil shells, iv. 39. 80.
Rita, hot spring of, its temperature raised by earthquake, ii. 230.
Rive, M. de la, on terrestrial magnetism, ii. 367.

Rivers, difference in the sediment of, i. 132. 341. 345. 369.; iii. 348.
——, sinuosities of, i. 258.
——, two equal, when they become confluent, do not occupy bed of double surface, i. 261.
Robert, M., on fossils of Cussac, iv. 150.
Rocco di Ferro, shells in tuffs of, iii. 425.
Rochester, indentations in the chalk filled with sand, &c. near, iv. 230.
Rockall bank, recent deposits on, iii. 294.
Rocks, specific gravity of, i. 260.
——, altered by subterranean gases, i. 328.; iv. 380.
——, distinction between sedimentary and volcanic, iii. 335.; iv. 344.
——, origin of the primary, iii. 336.; iv. 357.
——, distinction between primary, secondary, and tertiary, iii. 335.
——, persistency of mineral character, why apparently greatest in the older, iv. 320.
——, older, why most consolidated and disturbed, iv. 324, 325.
——, secondary volcanic, of many different ages, iv. 326.
——, relative age of, how determined, iii. 341.
——, transportation of, by ice, i. 265.; ii. 334.; iv. 61.
——, cleavage planes and jointed structure of, iv. 361.
——, how altered by permeation of heat and gases, iv. 378.
——, chemical composition of different, iv. 383.
Roderberg, crater of the, iv. 48. 119.
Rogvarpen, Lake, strata near, ii. 345.
Roman roads under water in Bay of Baiæ, ii. 321.
Rome, travertins of, iv. 43.
Romney Marsh, gained from sea, ii. 42.
Ronca, tertiary limestone of, iv. 224.
Ronchi, Roman bridge of, buried in silt, i. 348.
Rose, M. G., on hornblende and augite, ii. 223.
Ross, Captain, on icebergs in Baffin's Bay, i. 168.
Rossberg, slide of the, iii. 222.
Rotaro, Monte, structure of, ii. 115.
Rotation of the earth, currents caused by, ii. 9.
Rother, River, vessel found in its old bed, ii. 42.; iii. 267.
Rottingdean, iv. 274.
Royat, near Clermont, iv. 213.
Royle, Mr., i. 148.
Rozet, M., on loess of the Rhine, iv. 51.
Runn of Cutch described, ii. 241.
Runton, crag strata in cliffs near, iv. 96.
Rye formerly destroyed by sea, ii. 42.

S.

Sabine, Captain, on well at Chiswick, i. 299.
—— on distance to which waters of Amazon discolour the sea, ii. 85.
——, on current crossing the mouth of the Amazon, ii. 85.
Sabrina, island of, ii. 198. 248.
Saco, flood on the River, i. 289.
Saharunpore, buried town near, iii. 221.
St. André destroyed by a landslip, iii. 222.
St. Andrews, loss of land at, ii. 21.
——, a gun-barrel, fossil, with shells attached to it, near, iii. 270.
St. Christopher's, alternations of coral and volcanic substances in, iv. 36.
St. Domingo, subsidence of coast of, ii. 299.
——, hot springs caused by earthquake in, ii. 294.
——, fossil vases, &c. in, iii. 266.
St. Eustatia, tertiary formations in, iv. 36.
St. George, banks of, ii. 5.
St. Helena, tides at, ii. 2.
St. Hospice, tertiary strata of, iv. 39.
St. Jago, earthquake at, ii. 231.
St. Katherine's Docks, a fossil vessel found in, iii. 267.
St. Lawrence, Gulf of, elevated beaches in, ii. 99.; iv. 35.
——, earthquakes in, ii. 251.
St. Madeleine, near Nice, fossil shells of, iv. 81.
St. Maura, earthquakes in, ii. 237. 258.
St. Michael, siliceous springs of, i. 323.
St. Michael's Mount, ii. 49.; iv. 375.
St. Mihiel, limestone cliffs of, iv. 34.
St. Ouen, five sheets of water intersected in a well at, i. 302.
St. Peter's Mount, Maestricht, fossils of, iv. 284.
St. Romain, gypsum of, iv. 167.

St. Sebastian, overflowed by volcanic alluvions, ii. 146.
St. Ubes engulphed by earthquake, ii. 297.
St. Vincent's, volcanos of, ii. 245.; iv. 36.
——, counter currents in the air proved by eruption in, i. 183.
——, boa constrictor conveyed on drift-wood to, iii. 72.
Salisbury Craig, altered strata in, iv. 372.
Salt, on its deposition in the Mediterranean, ii. 67.
Salt springs, i. 29. 326.
Saltholm, island of, ii. 333.
Samothracian deluge, ii. 104.
San Ciro, fossils in cave of, iv. 53.
Sand, estuaries blocked up by blown, ii. 26. 73.
——, cones of, thrown up during earthquake, ii. 278.
——, drift, imbedding of towns, organic remains, &c. in, iii. 210. 212.
Sanda, its promontory cut off by the sea, ii. 18.
Sandown Bay, excavated by sea, ii. 44.
Sandstone, old red, fish found fossil in, i. 229. 238.
Sandwich Land, perpetual snow to level of sea-beach in, i. 171.
San Feliu de Palleróls, ravine in lava near, iv. 109.
San Filippo, travertin of, i. 312.
San Lio, on Etna, fissures in plain of, ii. 169.
San Lorenzo, isle of, recent fossils in, ii. 303.
San Lucido, torrents of mud caused by earthquake at, ii. 277.
San Quirico, hills of, iv. 68.
Santa Croce, Cape of, limestone on lava at, iii. 412.
Santa Madalena, section at, iv. 106.
Santa Margarita, crater of, iv. 107.
Santorin, geological structure of, ii. 206.
——, chart and section of, ii. 207.
——, new islands in Gulf of, ii. 208.
San Vignone, travertin of, i. 309.
Saracens, learning of the, i. 28.
Sardinian volcanos, iv. 114.
Sasso, Dr., on tertiary strata of Genoa, iv. 78.
——, on fossil shells of Albenga, iv. 79.
Saucats, freshwater limestone of, iv. 134.
Saussure on the Alps and Jura, i. 79.
—— on glaciers of Mont Blanc, i. 265.
Savanna la Mar, swept away by sea, iii. 221.
Savona, tertiary strata of, iv. 153.
Saxony, Werner on the geology of, i. 82.
Scandinavia represented as an island by the ancients, ii. 332.
——, gradual rise of, i. 212.; ii. 331. 384.; iv. 3. 38.
——. *See* Sweden.
Scarpellini, Professor, i. 99.
Scheuchzer, his theory, 1708, i. 57.
Scheveningen, waste of cliffs of, ii. 56.
Schist, siliceous, clay converted into, by a lava dike, iii. 414. 427.
Schlegel, M. de, i. 23.
Schmerling, Dr., on cavern of Chockier, iii. 233.
—— on human remains in caves, iii. 234.
Sciacca, island of. *See* Graham Island.
Scilla on organic remains, 1670, i. 41.
Scilla, rock of, ii. 279. 280.
Scoresby, Captain, on the gulf stream, i. 167.
——, on the formation of field ice, i. 186.
——, on weight of rocks transported by icebergs, i. 266.
——, cited, iii. 62. 241.; iv. 366.
Scotland, floods in, i. 262.; iii. 252.
——, fossil fish in old red sandstone of, i. 230.
——, waste of coast of, ii. 19.
——, slight earthquakes felt in, ii. 111.
——, thickness of alluvions in, ii. 285.
——, peat-mosses of, iii. 201. 207.
——, marl-lakes of, iii. 256. 282. 288.
——, granite veins of, iv. 346.
Scrope, Mr. G. P., on excavation of valleys, i. 259.
——, on eruption of Vesuvius in 1822, ii. 132.
——, on elevation craters, ii. 203. 223.
——, on volcanic district of Naples, iv. 26.
——, on volcanos of the Rhine, iv. 119.
——, on geology of Auvergne, iv. 198, 199. 207. 210.
——, on formation of pisolitic globules at Pompeii, ii. 149.
——, on eruption of Etna in 1811, ii. 174.
——, on advance of lava of 1819, ii. 175.
——, on cause of convexity of plain of Malpais, ii. 188.
——, on columnar basalts of Vesuvius, ii. 142.

Sea does not change its level, but land, i. 25.
——, Morò on manner in which it acquired its saltness, i. 61.
——, its influence on climate, i. 169.
——, area covered by, i. 216.
——, its encroachment on different coasts, ii. 12. 21. 43. 50.
——, cause of its rise and retreat during earthquakes, ii. 244. 298.
Sea-cliffs, successive elevations proved by, iv. 8.
——, manner in which the sea destroys successive ranges of, iv. 8. 242.
——, ancient, in the Morea, iv. 34.
——, in Peru, iv. 32.
Seaford, waste of cliffs at, ii. 43.; iv. 269.
Seals, migrations of, iii. 66.
Sea-water, density of, i. 168.
Sea-weed, banks formed by drift, iii. 37. 288.
Seckendorf, M. de, on greywacké slate, with organic remains in granite, i. 83.
Secondary rocks, iii. 281.; iv. 341.
—— of Weald Valley, iv. 235.
——, their rise and degradation gradual, iv. 264.
——, fossils of the, i. 153. 227.
——, no species common to tertiary and, iv. 285, 286. 290.
——, circumstances under which they originated, iii. 341.
——, why more consolidated and disturbed, iv. 323.
——, volcanic, of different ages, iv. 326.
Secondary freshwater deposits, why rare, iv. 320.
Secondary periods, duration of, iv. 290.
Sedgwick, Professor, on the Hartz mountains, i. 83.
——, on tertiary deposits of the Alps, i. 205.
——, on Caithness schists, i. 230.
——, on magnesian limestone, i. 314.
——, on the antagonist power of vegetation, iii. 181.
——, on preservation of organic remains in fissures, iii. 230.
——, on diluvial waves, iii. 454; iv. 218.
——, on tertiary formations of Styria, iv. 141. 143. 155.
——, on Isle of Wight, iv. 229. 273.
——, on granite veins, iv. 347.
——, on cleavage and jointed structure of rocks, iv. 361.
——, on garnets in altered shale, iv. 371.
Sediment, its distribution in the Adriatic, i. 348.
—— in river water, i. 362.
—— of Ganges compared to lavas of Etna, i. 365.
——, rate of subsidence of some kinds of, ii. 86.
——, area over which it may be transported by currents, ii. 86.
Sedimentary deposition, causes which occasion a shifting of the areas of, iii. 367.
—— rocks, distinction between volcanic and, iii. 335.
Seguinat, Montagne de, iv. 368.
Selside, fissure in limestone at, iii. 230.
Seminara, effects of earthquake near, ii. 269.
Seneca on a future deluge, i. 22.
Septaria of London clay described, iv. 227.
Serapis, temple of, ii. 312.
—— ground plan of environs of, ii. 312.
——, date of its re-elevation, ii. 323.
Serre del Solfizio, buried cones in cliffs of, iii. 438.
——, dikes at the base of, iii. 441.
Serres, E. R. A., on changes in brain of fœtus in vertebrated animals, iii. 19.
Serres, M. Marcel de, on changes in buried human bones, iii. 236.
——, on human remains in French caves, iii. 235. 237.
——, on drifting of land shells to the sea, iii. 382.
——, on tertiary strata of Montpellier, iv. 138.
——, on fossil insects of Aix, iv. 223.
Severn, tides in estuary of, ii. 3.
——, gain of land in its estuary, ii. 50.
Shakspeare cited, i. 228.
Shakspeare's cliff decays rapidly, ii. 39.
Shales, bituminous, i. 331.
Sheep, multiplication of, in South America, iii. 136.
Shell marl, fossils in, iii. 282. 322.
Shells. *See* Testacea.
Sheppey, fossils of, i. 238.
——, waste of the cliffs, ii. 35.
Sherringham, sections in cliffs of, iv. 97.
——, waste of cliffs at, ii. 25.; iv. 249.
Shetland Islands, action of the sea on, ii. 12. 18.; iv. 58.
——, rock masses drifted by sea in, ii. 13.
——, effect of lightning on rocks in, ii. 14.

Shetland Islands, granites of different ages in, iv. 350.
——, passage of trap into granite in, iv. 356.
——, formations now in progress near, iii. 295.
Ships, number of British wrecked annually, iii. 260. 263.
——, fossil, ii. 42.; iii. 210. 266.
Shropshire coal-field, i. 197.
Sibbald cited, iii. 71. 289.
Siberia, rhinoceros found entire in the frozen soil of, i. 79. 147.
——, the Bengal tiger found in, i. 144.
—— Lowland of, i. 149. 214.
—— drift-timber on coast of, iii. 246.
Siberian mammoths, i. 141.
Sicily, fossils of existing species in, i. 137.
——, earthquakes in, ii. 107. 252. 306.; iii. 229.
——, geological structure of, iii. 362. 405.
——, map of part of, iii. 404.
——, origin of newer Pliocene strata of, iv. 1.
——, form of valleys of, iv. 6.
——, no peculiar indigenous species found in, iv. 13.
——, caves in, iv. 51.
——, alluviums of, iv. 61.
Sidon, ancient site of, two miles from sea, ii. 83.
Siebengebirge, volcanic rocks of the, iv. 122.
Sienna, fossil shells of, i. 67. 138.
——, Subapennine strata near, iv. 69. 74.
Silex deposited by springs, i. 323.
——, piles of Trajan's bridge said to be converted into, i. 325.
Silla, subsidence of the mountain, ii. 245, 246.
Silliman, Professor, cited, iii. 267.
Silurian group of rocks, iv. 283.
——, term, whence derived, iv. 306.
Silvertop, Colonel, on tertiary strata of Spain, iv. 84.
Simeto, R., lava excavated by, i. 268.
——, plain of the, iii. 422.
Sindree, changes caused by earthquake of 1819 near, ii. 238.; iii. 274.
——, view of the fort of, before the earthquake (*see* Pl. 6.), ii. 238.
Sioule, R., ravines cut through lava by, iv. 207.
Sipparah, R., its course changed, iii. 216.
Skaptâ, R., its channel filled by lava, ii. 181.
Skaptár Jokul, eruption of, ii. 181.
Sky, granite of, iv. 350.
Slate rocks, cleavage planes of, iv. 361.
Slave Lake, drift-timber in, iii. 243.
Sleswick, waste of coast of, ii. 59.
Sligo, bursting of a peat-moss in, iii. 208.
Sloane, Sir H., on earthquake in Jamaica, ii. 309.
——, on dispersion of plants, iii. 35.
Smeaton on effect of winds on the surface of water, ii. 7.
Smith, William, agreement of his system with Werner's, i. 83.
——, his 'Tabular View of the British Strata,' 1790, i. 101.
——, his Map of England, i. 102.
——, priority of his arrangement, i. 102.
Smith, Sir J., cited, ii. 445.; iii. 40.
Smyrna, volcanic country round, ii. 106.
Smyth, Capt. W. H., on the Mediterranean, i. 78. 344.; ii. 317.
——, on height of Etna, ii. 164.
——, on Straits of Gibraltar, ii. 68. 70.
——, on depth of sea from which Graham Island rose, ii. 199.
——, on floating islands of drift-wood iii. 64.
——, on drifting of birds by the wind, iii. 70.
——, on diffusion of insects, iii. 87.
——, on average number of British ships lost from 1793 to 1829, iii. 263.
——, found shells at great depths between Gibraltar and Ceuta, iii. 294.
——, on volcanos of Sardinia, iv. 114.
Snow, height of perpetual, in the Andes, i. 190.
—— in Himalaya mountains, i. 190.
Södertelje, canal of, ii. 338.
——, recent strata of, ii. 344.
——, buried hut in, ii. 347.
Sodom, catastrophe of, mentioned by Hooke, i. 50.
Soil, its influence on plants, ii. 446.
Soils, on formation of, iii. 177.
——, influence of plants on, iii. 108.
Soldani, theory of, 1780, i. 77.
—— on microscopic testacea of Mediterranean, i. 77.
—— on the Paris basin, i. 77.
Solenhofen, fossils of, iv. 299.
Solent, its channel becoming broader, ii. 45.
Solfatara, lake of, i. 316.
——, volcano, ii. 117. 122. 126. 130.
——, effects of the exhalations on its structure, ii. 143.; iv. 381.

Solfatara, temple of Serapis probably submerged during eruption of, ii. 324.
Solon on Island of Atlantis, i. 13.
Solway Moss, a man and horse, in armour, found in, iii. 208.
——, bursting of, iii. 208.
Solway Firth, animals washed by river-floods into, iii. 252.
Somersetshire, land gained in, ii. 50.
Somerville, Mrs., on the earth's axis of rotation, i. 156.
——, on depth of Atlantic and Pacific Oceans, i. 180.
——, on effects of compression at earth's centre, ii. 355.
Somma, escarpment of, iii. 433, 434. 437. 448.
——, dikes of, ii. 140.; iv. 20.
——, changes caused by dikes in, iii. 441.
—— and Vesuvius, differences in composition of, iv. 18.
——, section of, ii. 138.
Somme, peat-mosses in valley of, iii. 210.
Sorbonne, College of the, i. 68.
Sorea, eruption in island of, ii. 306.
Soriano, changes caused by earthquake near, ii. 262. 273.
Sortino, limestone formation in valleys of, iii. 407.
——, caves near, iv. 52.
Sortino Vecchio, several thousand people entombed at once in caverns at, iii. 229.
South Carolina, earthquake in, ii. 246.
South Downs, waste of plastic clay on, ii. 43.
——, chalk ridge called the, iv. 236.
——, section from, to the North Downs across Weald Valley, iv. 237.
——, highest point of, iv. 237.
——, escarpment of, iv. 246.
——, section from, to Barcombe, iv. 247.
——, on former continuity of chalk of North and, iv. 257.
Souvignargues, cave at, iii. 236.
Spaccaforno limestone, iii. 408.
Spada, his theory, i. 59.
Spain, earthquakes in, ii. 109.
——, tertiary formations of, iv. 84.
——, extinct volcanos of, iv. 103.
——, lavas excavated by rivers in, iv. 106. 110.
Spallanzani on effects of heat on seeds of plants, iii. 35.
—— on flight of birds, iii. 69.
Spanish lake, i. 286.
Species, definition of the term, ii. 405.
——, Linnæus on constancy of, ii. 407.
——, Lamarck's theory of transmutation of, ii. 407. 430.; iii. 161.
——, reality of, in nature, ii. 436. 451.; iii. 20.
——, geographical distribution of, iii. 22. 393.
——, theories respecting their first introduction, iii. 98. 167.
——, Brocchi on extinction of, iii. 104.
——, reciprocal influence of aquatic and terrestrial, iii. 119.
——, their successive destruction part of the order of nature, iii. 122. 154. 164. 172.
——, effect of changes in geography, climate, &c. on their distribution, i. 177.; iii. 144. 156. 159. 353. 372.
——, superior longevity of molluscous, i. 142.; iii. 383.; iv. 52.
——, necessity of accurately determining, iii. 383.
——, living, proportion of, in different tertiary periods, iii. 391. 395.
—— in Sicily older than country they inhabit, iv. 13.
——, none common to secondary and tertiary formations, iv. 285, 286.
Spence, Mr., on insects, cited, iii. 12. 84. 114.
Spina, ancient city in delta of Po, i. 347.
Spinto, fossil shells at, iv. 139.
Spitzbergen, glaciers of, i. 168.
Spix, M., on drifting of animals by the Amazon, iii. 63.
—— on Brazil, iii. 129.
Spontaneous generation, theory of, i. 57.
Sprengel, M., on numbers of plants, iii. 170.
Springs, origin of, i. 296.
——, the theory of, illustrated by bored wells, i. 298.
—— most abundant in volcanic regions, i. 305.
—— affected by earthquakes, i. 305.; ii. 230. 271. 294.
——, transporting power of, i. 133. 307.
——, calcareous, i. 307. 321.
——, sulphate of magnesia deposited by, i. 312.
——, sulphureous and gypseous, i. 322.
——, siliceous, i. 323.
——, ferruginous, i. 326.
——, brine, i. 326.
——, carbonated, i. 327.

Springs, petroleum, i. 329.
Spurn Point, its rapid decay, ii. 23.
Squirrels, migrations of, iii. 57.
Stabiæ, buried city of, ii. 159.
Stalagmite alternating with alluvium in caves, iii. 232.
Start Island separated from Sanda by sea, ii. 18.
Statical figure of the earth, ii. 352. 372.
Stations of plants, description of, iii. 25.
—— of animals, iii. 121.
Staunton, Sir G., on sediment in Yellow River, i. 362.
Staveren, formation of Straits of, ii. 40. 57.; iii. 151.
Steele on Burnet's theory, i. 55.
Steininger, M., on loess of the Rhine, iv. 48. 51.
——, on volcanic district of the Eifel, iv. 126.
——, on greywacké rocks, iv. 306.
Stelluti on organic remains, i. 38.
Steno, opinions of, i. 39.
Stephensen on eruption in Iceland, ii. 180.
Steppes, Russian, geology of the, ii. 103.
Sternberg, Count (cited by mistake), on changes of climate, i. 215.
—— on the coal strata, i. 197.
Stevenson, Mr., on drift stones thrown on the Bell Rock, ii. 20.
——, on the German Ocean, ii. 39. 81.
——, on waste of cliffs, ii. 50.
Stewart, Dugald, cited, i. 244.
Steyning, chalk escarpment above, iv. 241.
Stirling Castle, altered strata in rock of, iv. 372.
Stockholm, rise of land near, ii. 337.
—— upraised deposits of shells near, ii. 342. 344. 346.
Stonesfield, fossils of, i. 232.; iv. 299.
Storm of November, 1824, effect of, ii. 43. 45. 48.
Stour and Avon, cliffs undermined, ii. 45.
Strabo cited, i. 23. 342. 350.; ii. 108. 114.
Straits of Dover, formation of, ii. 40.
——, their depth, ii. 39, 40.
Straits of Staveren, formation of, ii. 40. 57.
Straits of Gibraltar, currents in, &c. ii. 66. 69. 73.
Stralsund, ii. 333.
Strata, cause of limited continuity of, iii. 334.
Strata, order of succession of, iii. 340.
——, origin of European tertiary, at successive periods, iii. 357.
——, recent, form a common point of departure in all countries, iii. 400.
——, with and without organic remains alternating, iv. 194.
——, fossiliferous, classification of the, iv. 282.
——, on consolidation of, iv. 324.
Stratification, in deltas, causes of, i. 372.
—— of débris deposited by currents, i. 374.; ii. 88.
——, unconformable, remarks on, iii. 371.
—— of the Crag, iv. 91.
—— of primary rocks, iv. 360.
——, difference between cleavage and, iv. 361.
Strato, hypothesis of, i. 24.
Stratton, Mr., on buried temples in Egypt, iii. 211.
Strickland, Mr., on tertiary strata near Cropthorn, i. 142.
Strike of beds, explanation of term, iv. 338.
Stromboli, its appearance during Calabrian earthquakes, ii. 280.
——, lava of, iv. 357.
Studer, M., on loess of the Rhine, iv. 45.
——, on molasse of Switzerland, iv. 140.
——, on theory of M. E. de Beaumont, iv. 340.
Stufas, jets of steam, in volcanic regions, i. 304.
Stutchbury, Mr., on coral islands, iii. 301. 303, 304. 318.
Styria, tertiary formations of, iv. 141. 155.
Subapennine strata, i. 138. 204. 236.; ii. 259.; iv. 63.
——, early theories of Italian geologists concerning, i. 73. 124.
——, opinions of Brocchi on the, iv. 63.
——, subdivisions of, described, iv. 67.
——, how formed, iv. 70.
——, organic remains of the, iv. 73.
Subaqueous strata, imbedding of fossils in, iii. 281.
——, our continents chiefly composed of, iii. 335.
——, how raised, iv. 3.
——, distinction between alluvium and, iii. 218.
Submarine forests, ii. 20. 50.; iii. 274. 276.

Submarine peat, iii. 209. 288.
Submarine volcanos, ii. 198.
Subsidence of land, ii. 237. 244. 245. 251, 252. 262. 276. 296. 300. 307. 313.; iii. 146. 272. 278. 316. 447.
—— and elevation, effects of alternate, i. 288.
——, permanent, ii. 383.
—— greater than elevation, ii. 400.
Subterranean lava causes elevation of land, iv. 4.
Successive development of organic life, i. 222.
Suez, Isthmus of, ii. 83.
Suffolk, cliffs undermined, ii. 29.
——, inland cliff on coast of, ii. 30.
——, tertiary strata of, iii. 358.; iv. 85.
Sullivan's Island, waste of, ii. 61.
Sulphur Island, ii. 100.
Sulphureous springs, i. 322.
Sumatra, volcanos in, ii. 101.
Sumbawa, subsidence in island of, 1815, ii. 242.; iii. 277.
Sunderbunds, part of delta of Ganges, i. 354.
Sunderland, magnesian limestone of, i. 315.
Superga, fossil shells of the, iii. 386.; iv. 138.
Superior Lake, deltas of, i. 338.
——, recent deposits in, i. 340.; iii. 285.
——, its depth, extent, &c., i. 338. 340.
——, bursting of, would cause a flood, iv. 214.
Superposition of successive formations, causes of the, iii. 367.
——, proof of more recent origin, iii. 342.
——, exceptions in regard to volcanic rocks, iii. 343.
——, no invariable order of, in Hypogene formations, iv. 387.
Surface, state of, when secondary and tertiary strata were formed, iii. 363.
Sussex, Weald formation of, i. 201.
——, waste of its coast, ii. 43.
Swanage Bay excavated by sea, ii. 45.
Swatch in Bay of Bengal, i. 355.
Sweden, gradual rise of, ii. 331. 397.; i. 211.; iv. 38. 40. 264.
——, earthquakes in, ii. 348.
——, age of alluvium of, iv. 62.
——, lignite of chalk period in, iv. 289.
——, greywacké rocks of, iv. 307.
——. *See* also Scandinavia.
Swinburne, Capt., on Graham Island, ii. 200. 203.
Switzerland, towns destroyed by landslips in, iii. 222.
——, 'molasse' of, iv. 140.
Symes on petroleum springs, i. 330.
Syenites not distinguishable from granites, iv. 351.
Syracuse, section at, iii. 407.
——, shells in limestone of, iii. 408.
——, inland cliffs north of, iv. 8.
——, caves near, iv. 52.
Syria, gain of land on its coasts, ii. 83.
——, earthquakes in, ii. 106.

T.

Table-Mountain, intersected by veins, iv. 346.
Tacitus cited, ii. 120.
Tadeausac, earthquakes at, ii. 251.
Tagliamento, R., delta of the, i. 346.
——, conglomerates formed by, i. 348.
Tampico, sediment transported by, ii. 85.
Tanaro plains of the, iii. 386.; iv. 139.
Tangaran, R., stopped up by landslips, ii. 305.
Targioni on geology of Tuscany, i. 69.
——, on origin of valleys, i. 69.
——, on fossil elephants, i. 70.
——, on deposits of springs, i. 309.
Taro, R., iv. 70.
Tay, encroachment of sea in its estuary, ii. 21.
Taylor, Mr. on art of mining in England, i. 80.
Taylor, Mr. R. C., on waste of cliffs, ii. 26.
——, on gain of land on coast of Norfolk, ii. 27.
——, on the formation of Lowestoff Ness, ii. 30.
Tech, R., tertiary strata in valley of, iv. 83.
Teissier, M., on human bones in caves, &c., iii. 237.
Temminck, cited, iii. 51. 171.
Temperature, great changes in, i. 159.
——, difference of, in places in same latitudes, i. 163.
——, causes of change in, i. 173.
——. *See* Climate.
Temples, buried, in Egypt, iii. 210.

Temruk, earthquakes frequent round, ii. 106.
Teneriffe, its peak an active solfatara, ii. 191.
——, volcanic eruptions of, ii. 192.
Ter, R., valley of the, iv. 104.
Terni, limestone forming near, i. 315.
Teronel, R., lava excavated by, iv. 110.
Terraces, manner in which the sea destroys successive lines of, iv. 8. 242.
Terranuova, subsidence near, ii. 252.
——, fault in the tower of, ii. 263.
——, landslips near, ii. 272.
——, tertiary strata at, iii. 419.
Tertiary formations, general remarks on the, i. 234.; iii. 341.
——, origin of the European, at successive periods, iii. 357.
——, circumstances under which these and the secondary formations may have originated, iii. 364.; iv. 315.
——, state of the surface when they were formed, iii. 365.
——, classification of, in chronological order, iii. 378.
——, new subdivisions of the, iii. 384.
——, numerical proportion of recent shells in different, iii. 391. 395.
——, mammiferous remains of successive, iii. 401.
——, Synoptical Table of Recent and, iii. 403.
——, identity of their mineral composition no proof of contemporaneous origin, iv. 71.
——, no species common to secondary and, iv. 285, 286. 290.
——, of Auvergne, iv. 147. 157.
——, of England, iii. 357, 358.; iv. 39. 85. 224.
——, of the Paris basin, iii. 354.; iv. 177.
——, of Sicily, iii. 405.
——, marine, iii. 354. 357. 405, 420.; iv. 1. 16. 63. 127. 177. 221.
——, freshwater, iv. 42. 150. 156.
——, volcanic, iii. 411. 423.; iv. 18. 102. 153. 197.
Testa and Fortis on fossil fish of Monte Bolca, i. 77.
Testacea, their geographical distribution, iii. 76.
——, fossil, importance of, iii. 381.
——, marine, imbedding of, iii. 292. 349. 381.
——, freshwater, iii. 288.
——, burrowing, iii. 294.
Testacea, parasitic, iii, 305.
——, longevity of species of, i. 142.; iii. 383. 394.; iv. 52.
—— recent, number of, in different tertiary periods, iii. 391. 395.
Tet, valley of, tertiary strata in, iv. 83.
Texel, waste of islands at its mouth, ii. 57.
Thames, gain and loss of land in its estuary, ii. 35.
——, tide in its estuary, ii. 76.
——, buried vessel in alluvial plain of the, iii. 267.
——, basin of the, iii. 357.
Thanet, Isle of, loss of land in, ii. 38.
Theorizing in geology, different methods of, iii. 325.
Thermo-electricity, ii. 367.
Thompson, Dr., on siliceous incrustations near Monte Vico, i. 325.
Thrace subject to earthquakes, ii. 108.
Thucydides on eruptions of Etna, ii. 168.
Thun, Lake of, delta of the Kander in, iv. 83.
Thury, M. Hericart de, on Artesian wells, i. 299.
Tiber, growth of its delta, i. 317.
——, valley of the, iv. 44.
Tide wave of the Atlantic, ii. 29.
Tides, height to which they rise, i. 356. ii. 263.
——, effect of winds on the, ii. 7.
——, effects of, on wells near London, i. 297.
——, their destroying and transporting power, ii. 1.
——, their reproductive effects, ii. 74.
—— and currents, drifting of remains of animals by, iii. 257.
Tiedemann on changes in the brain in the fœtus of vertebrated animals, iii. 18.
Tierra del Fuego supposed to contain active volcanos, ii. 93.
Tiflis, earthquakes at, ii. 105.
Tiger of Bengal found in Siberia, i. 144.
Tigris and Euphrates, their union a modern event, i. 371.
Tiganux, tower of, i. 343.
Tilesius on Siberian mammoth, i. 149.
Time, prepossessions in regard to the duration of past, i. 111.; iii. 449.
——, error as to quantity of, fatal to sound views in geology, i. 114.

Time, great periods required to explain formation of sedimentary strata, i. 127.
Timor, Island of, iv. 40.
Tivoli, flood at, i. 294.
——, travertin of, i. 318.
Toledo, Signor, on elevation of coast of Bay of Baiæ, ii. 327.
Tomboro, volcano, eruption of, ii. 243.
——, town of, submerged, ii. 244.
Torneo, gain of land at, i. 341. ; ii. 334.
Torre del Annunziata, columnar lava at, ii. 142.
Torre del Greco overflowed by lava, ii. 159.
——, columnar lavas of Vesuvius seen at, ii. 141.
Torrents, action of, in widening valleys, i. 258.
Torum, overwhelmed by sea, ii. 58.
Tory Island, living testacea at great depths off, iii. 294.
Totten, Col., on expansion of rocks by heat, ii. 383.
Touraine, tertiary strata of, iii. 359. ; iv. 128.
Tournal, M., on French caves, iii. 235. 237.
Tours, shells, &c. brought up in a bored well at, i. 303.
Towns destroyed by landslips, iii. 222.
Trade winds, i. 183. ; ii. 8.
Traditions of losses of land, ii. 49, 50, 51.
Transition formations, fossils of, i. 196. 229.
——, their extent, i. 195. *See* Greywacké.
Transverse valleys in North and South Downs, iv. 250.
Transylvania, tertiary formations of, iv. 141. 144. 155.
Trap rocks, origin of the term, iv. 353.
——, passage of, into granite, iv. 355.
Trass of Rhine volcanos, iv. 121.
Travertin of the Elsa, i. 308. ; iv. 42.
—— of San Vignone, i. 309.
—— of San Filippo, i. 312.
——, spheroidal structure of, i. 313.
——, compared to the English magnesian limestone, i. 314.
—— of Tivoli, i. 318.
——, oolitic, recent formation of, in Lancerote, ii. 197.
—— in Forfarshire, iii. 282.
—— of Rome, fossils in, iii. 407.
Trees, longevity of, iii. 451. ; iv. 217.
Trezza, travertin formed by spray of the sea on rocks of, ii. 197.
——, Bay of, sub-Etnean formations in the, iii. 424.
——, submarine eruptions in, iii. 424. 428
Trimmer, Mr., on recent marine shells in Wales, i. 211.
Trimmingham, sections near, iv. 90. 99.
Trinidad, subsidence in, i. 330.
——, pitch lake of, i. 330.
—— earthquakes in, ii. 294.
Tripolitza, plain of, breccias forming in, iii. 227.
Trollhättan, ii. 343.
Truncated volcanic cones, 216. 293.
Tufa, calcareous, of Rome, iv. 43.
Tuff, dikes of, how formed, iii. 414.
——, shells in, iv. 26.
Tunguragua volcano, ii. 95, 96. 250.
Tunza, R., ii. 231.
Turin, tertiary formations of, iv. 138.
Turtles, migrations of, iii. 71.
——, eggs of, fossil, iii. 290.
Turton cited, iii. 62. 72.
Tuscany, geology of, i. 39. 69.
——, calcareous springs of, i. 308.
——, freshwater formations of, iv. 42.
——, volcanic rocks of, iii. 387. ; iv. 102.
Tyre now far inland, ii. 83.
Tyrol, Dolomieu on the, i. 86.

U.

Uddevalla, upraised deposits of shells at, ii. 342.
Ullah Bund, formation of the, ii. 239.
Ulloa cited, ii. 301. ; iii. 136.
Unalaschka, new island near, ii. 248.
Unconformability of strata, remarks on the, iii. 371. 375.
Uniformity of Nature, i. 125. 250. ; ii. 127.
Universal formations of Werner, i. 83.
—— remarks on theory of, iii. 345. ; iv. 322.
Universal ocean, theory of an, i. 45. 59.
—— disproved by organic remains, i. 134.
Upsala, strata near, ii. 344.
Urmia, lake, springs near, i. 322.
——, its size, &c., ii. 106.

V.

Val d'Arno, Upper, lacustrine strata of, iv. 71. 150.
——, fossils of the, i. 237. ; iv. 151.
——, effect of destruction of forests in, iii. 185.
Val del Bove on Etna described, iii. 430. 436. 442.
——, section of buried cones in, iii. 438.
——, form, composition, and origin of the dikes in, iii. 437. 440.
——, lavas and breccias of the, ii. 174. ; iii. 445.
——, origin of the, iii. 446.
——, floods in, ii. 176. ; iii. 448.
Valdemone, formations of, iii. 420.
Val di Calanna, its shape, &c., iii. 434.
—— began to be filled up by lava in 1811 and 1819, ii. 176. ; iii. 436.
Val di Noto, Dolomieu on the, i. 86.
——, formations of the, iii. 405.
——, volcanic rocks of the, iii. 406. 411. ; iv. 354.
——, volcanic conglomerates of, iii. 417.
——, form of valleys of, iv. 6.
——, inland cliffs on east side of, iv. 8.
Vale of Pewsey, iv. 263.
Valle das Furnas, hot springs of, i. 323.
Valley of the Nadder, iv. 263.
Valleys, Targioni on origin of, i. 69.
——, excavation of, in Central France, i. 268.
—— of elevation, iv. 259.
—— on Etna, account of, iii. 430.
—— of Sicily, their form, iv. 7.
——, the excavation of, assisted by earthquakes, ii. 281. ; iv. 11.
——, transverse, of North and South Downs, iv. 250. 252.
—— of S.E. of England, how formed, iv. 276.
Vallisneri on origin of springs, i. 58.
—— on marine deposits of Italy, i. 58.
—— on the danger of connecting theories in physical science with the sacred writings, i. 58.
——, universal ocean of, i. 59.
—— on primary rocks, i. 90.
Valmondois, tertiary strata of, iv. 186.
Valognes, tertiary strata of, iv. 221.
Valparaiso, changes caused by earthquakes at, ii. 231. 235. 323. ; iii. 273.
——, gain of land at, ii. 234.
Van der Wyck, M., on the Eifel, iv. 126.
Van Diemen's Land, climate of, i. 170.
Var, R., gravel swept into sea by, iv. 79. 82.
Vatican, hill of the, tufa on, iv. 43.
Veaugirard, alternation of calcaire grossier and plastic clay at, iv. 181.
Vegetable soil, why it does not increase, iii. 177.
——, how formed, iii. 179.
Vegetation, centres of, iii. 166.
——, its conservative influence, iii. 180. 184.
——, its influence on climate, iii. 187.
Veins, mineral, on their formation, ii. 271. ; iv. 381.
—— of lava. *See* Dikes.
Velay, extinct quadrupeds in volcanic scoriæ in, iv. 149. 203.
——, freshwater formations of, iv. 170.
——, volcanic rocks of, iv. 155. 201. 203.
Vera Cruz destroyed by earthquake, ii. 303.
Verdun, markings on cliffs near, iv. 34.
Verona, fossils of, i. 33. 37. 59.
——, Arduino on mountains of, i. 71.
Vertebrated animals in oldest strata, i. 232.
Vessels, fossil. *See* Ships.
Vesta, temple of, i. 295.
Vesuvius, excavation of tuff on, i. 268.
——, history of, ii. 118. 131.
——, eruptions of, ii. 118. 129. 131. ; iii. 447.
——, dikes of, ii. 137. ; iv. 20. 22.
——, lava of, ii. 141. 145.
——, volcanic alluvions on, iii. 214.
—— and Somma, difference in their composition, iv. 18.
——, probable section of, ii. 138.
Vicentin, Dolomieu on the, i. 86.
——, submarine lavas of the, i. 125.
——, tertiary strata of the, iv. 224.
Vicenza, mountains of, i. 71.
Vichy, tertiary oolitic limestone of, iv. 165.
Vidal, Captain, on Rockall bank, iii. 294.
Vienna, gypseous springs of, i. 22.
——, tertiary formations of, iii. 361. ; iv. 141.
Vigolano, gypsum and marls at, iv. 68.
Villages and their inhabitants buried by landslips, iii. 222.
Villarica volcano, ii. 94.
Villasmonde, limestone of, iii. 407.

Villefranche, Bay of, strata near, iv. 39.
Vinegar R., sulphuric acid, &c. in waters of, iv. 191.
Virgil cited, i. 244.
Virlet, M., on deluge of Samothrace, ii. 105.
——, on volcanos of Greece, ii. 108.
——, on greywacké fossils, i. 196.
——, on island of Santorin, ii. 206. 210, 211.
——, on corrosion of hard rocks by subterranean gases, iii. 224.; iv. 380.
——, on imbedding of human bones in the Morea, iii. 227.
——, on geology of the Morea, iv. 84. 288.
Viterbo, travertin of, i. 315.
——, tuffs and marls at, iv. 68.
——, volcanic rocks of, iv. 102.
Vito Amici on Moro's system, i. 66.
Vivarais, basalts of the, i. 85.
Vivenzio on earthquake of Calabria in 1783, ii. 255. 277.
Viviani, Professor, on Sicilian flora, iv. 13.
——, on tertiary strata of Genoa, iv. 78.
Vizzini, tuff and limestone near, iii. 414.
——, changes caused by a dike of lava at, iii. 414.
——, oyster-bed between two lava currents, at, iii. 418.
Volcanic action, defined, ii. 91.
——, uniformity of, iii. 183.
Volcanic breccias, how formed, iv. 200.
Volcanic cones, truncation of, ii. 216. 293.
——, their perfect state no proof of their relative age, iii. 186.
Volcanic conglomerates, iii. 417.
Volcanic dikes. *See* Dikes.
Volcanic eruptions, causes of, ii. 363.
——, average number of, per annum, ii. 224.
Volcanic formations, fossils in, iii. 213.
Volcanic lines, modern, not parallel, iv. 340.
Volcanic products, mineral composition of, ii. 223.
Volcanic regions, their geographical boundaries, ii. 93.
——, map showing extent of (see plate 3.), ii. 99.
Volcanic rocks, subterranean, ii. 225.
Volcanic rocks, distinction between sedimentary and, iii. 335.
——, distinction between plutonic and, iv. 352.
——, age of, how determined, iii. 343.
—— of the Val di Noto, iii. 411.
—— of Campania, iv. 16.
—— of Italy, iv. 102.
—— of Hungary, Transylvania, and Styria, iv. 153.
—— of Central France, iv. 197.
—— secondary, of many different ages, iv. 326.
Volcanic vents, remarks on their position, ii. 92. 391.
Volcanos, safety valves according to Strabo, i. 26.
——, duration of past time proved by extinct, i. 129.
——, agency of water in, ii. 391.
——, mode of computing the age of, iii. 449.
—— sometimes inactive for centuries, iii. 450.
—— the result of successive accumulation, iv. 175.
Volhynia, tertiary formations of, iv. 144.
Voltaire, his dislike of geology, i. 95.
—— on systems of Burnet and Woodward, i. 95.
Volterra, Mattani on fossils of, i. 59.
Voltz, M., on loess of the Rhine, iv. 51.
Von Buch on rise of land in Sweden, i. 211.; ii. 336. 342.
—— on volcanos of Greece, ii. 108.
—— on eruption in Lancerote, ii. 192.
—— his theory of elevation craters considered, ii. 206.
—— on new island near Kamtschatka, ii. 248.
—— on the Eifel, iv. 126.
—— on tertiary formations of Volhynia and Podolia, iv. 144.
—— on volcanic lines, iv. 340.
Von Dechen, M., on volcanic district of Lower Rhine, iv. 126.
——, on the Hartz mountains, iv. 339.
——, on granite veins, iv. 346.
Von Hoff. *See* Hoff.
Von Oeynhausen on the Eifel district, iv. 115.
——, on granite veins, iv. 346.
Vosges, loess near their base, iv. 45.
Vulcanists, persecution of, in England, i. 97.

Vulcanists and Neptunists, factions of, i. 87.
Vultures, range of, iii. 67.

W.

Waal, R., ii. 53. 54.
Wahlenberg, Professor, on greywacké of Sweden, iv. 307.
Wales, slate rocks of, iv. 361. 389.
Wallerius, theory of, i. 78.
Wallich, Dr., on Ava fossils, i. 49.
Walton, sections near, iv. 91. 93.
Walton Naze cliffs, undermined, ii. 35.
Warburton, Mr., on Bagshot sand, iv. 228.
Ward, Mr., on Kentucky caves, iii. 224.
Warp of the Humber, i. 373. ; ii. 79.
Warton, his eulogy on Burnet, i. 55.
Washita, R., raft on, i. 282.
Water, action of running, i. 256.
——, its power on freezing, i. 257.
——, solvent power of, i. 257.
——, excavating power of, i. 258.
——, transporting power of, i. 260.
——, agency of, in volcanos, ii. 391.
——, absorption of carbonic acid by, iv. 379.
Watt, Gregory, his experiments on rocks, iv. 24. 377.
Weald, denudation of valley of the, iv. 234. 272.
——, secondary rocks of the, iv. 235.
——, section of valley of the, iv. 236. 237.
——, alluvium of valley of the, iv. 247.
Wealden, secondary group, called the, iv. 291.
——, organic remains of the, iv. 292. 296.
——, its extent, thickness, &c., iv. 315.
Weaver, Mr., on coal of Munster, i. 196.
Webster, Dr., on hot springs of Furnas, i. 324.
Webster, Mr., on waste of Sussex cliffs, ii. 43.
——, on geology of I. of Wight, iii. 357. ; iv. 266. 273.
——, on formations of London and Hampshire basins, iv. 226. 228.
——, on fossil forest of I. of Portland, iv. 295.
Weddell, Captain, latitude reached by, i. 171.
Wellington Valley, Australia, fossils in breccias in, iv. 56.
Wells, influence of the tides on, near London, i. 297.
Wells, Artesian, i. 298.
Wener, lake, strata near, ii. 344.
Wenlock rocks, iv. 283, 284. 306.
Werner, Professor of mineralogy at Freyberg, 1775, i. 80.
——, his lectures, i. 82.
——, universal formations of, i. 83.
—— on granite of the Hartz, i. 83.
——, principal merit of his system, i. 83.
——, his theory of basalt, i. 84.
—— taught that there were no volcanos in the primeval ages, i. 84.
——, technical terms of, i. 102.
——, on transition rocks, iii. 340.
West Indies, Hooke on earthquake in, i. 50.
——, active volcanos in, ii. 98.
——, tertiary formations of, iv. 36.
Wey, transverse valley of the, iv. 251.
Whales stranded, iii. 289.
Whewell, Rev. Mr., on modern progress of geology, i. 104.
——, on the tides, ii. 61.
——, cited, i. 180. ; iii. 391.
Whirlwinds, violent, during eruption in Sumbawa, ii. 243.
——, dispersion of seeds by, iii. 32.
Whiston, his Theory of the Earth, i. 55.
——, refuted by Keill, i. 57.
White Mountains, landslips in the, i. 289.
Whitehurst, theory of, 1778, i. 78.
——, on rocks of Derbyshire, i. 78.
——, on subsidence at Lisbon, ii. 296.
Whitsunday Island, description of, iii. 307.
Wiegmann on hybrids, iii. 4, 5.
Wildon, coralline limestone of, iv. 142.
Willdenow on diffusion of plants by man, iii. 44.
—— on centres of vegetable creation, iii. 166.
Williams on Hutton's theory, i. 97.
Wiltshire, valleys of elevation in, iv. 263.
Wily, valley of the, iv. 263.
Winchelsea destroyed by sea, ii. 42.
Winds, trade, i. 183. ; ii. 3. 8.
——, currents caused by the, ii. 7.
——, sand drifted by the, ii. 73.
Wismar, ii. 333.
Wodehouse, Captain, on Graham Island, ii. 200.
Wokey Hole, human remains in, iii. 234.
Wolf, and dog, distinct species, ii. 438.
——, hybrids between the, iii. 3.
—— drifted to sea on ice, iii. 62.

Wolf, extirpated in Great Britain, iii. 131.
Wollaston, Dr., on water of Mediterranean, ii. 68.
—— cited, ii. 165.
Wood, Mr., on fossils of the Crag, iv. 86, 87.
Wood impregnated with salt water when sunk to great depths, iii. 241.
——, drift, i. 158. 281. 361.; iii. 62. 243.
—— converted into lignite, iii. 268.
Woodward, theory of, i. 53. 58. 95. 117.
Woodward, Mr. S., on geology of Norfolk, iv. 100.
Wrecks, average number of, per year, iii. 260. 262.
Wrotham Hill, height of, iv. 237.

X.

Xanthus, the Lydian, his theory, i. 24.

Y.

Yarmouth, estuary silted up at, ii. 27.
——, rise of the tide at, ii. 3. 27.
——, thickness of crag near, iv. 89.
Yates, Rev. J., on delta of the Kander, iv. 83.
Yellow R., sediment in, i. 362.
Yenesei R., fossil bones on banks of, i. 145.
Yorkshire, bones of mammoth in, i. 142.
——, waste of its coasts, ii. 22.
——, chalk of, iv. 269.
Young, Dr., on effects of compression at earth's centre, ii. 355.
Ytrac, freshwater flints at, iv. 172.

Z.

Zaffarana, valleys near, iii. 433.
Zante, earthquakes in island of, ii. 258.
Zechstein formation, iv. 301.
Zingst peninsula converted into an island, ii. 65.
Zocolaro, hill of, lava of Etna deflected from its course by, iii. 436.
Zoological provinces, how formed, iii. 100.
——, why not more blended together, iii. 103.
——, great extent of, iii. 347.
Zoophytes, their geographical distribution, iii. 82.
——, their powers of diffusion, iii. 82.
——, abundance of, iii. 171.
——, which form coral reefs, iii. 299.
Zuyder Zee, formation of, ii. 56.

THE END.

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